DEPARTMENT OF
SCIENTIFIC AND INDUSTRIAL RESEARCH

ENGINEERING DESIGN

Correction

Page 55. *Line* 3.

Sir Ewart Smith gave evidence in his personal capacity and is *not* connected with *Short Brothers and Harland Ltd., Belfast.*

LONDON: HER MAJESTY'S STATIONERY OFFICE
July 1963
51747 Wt. 3079—146 3750 7/63 St.S.

ENGINEERING DESIGN

Report to the Council for Scientific and Industrial Research

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

BRITAIN'S share of international trade in engineering goods has been declining. In spite of some notable successes, too many British products are being outclassed in performance, reliability and sales appeal. Imports of machinery have been increasing.

Engineering goods are sold on the merits of their performance, reliability, appearance, delivery and price. Design determines most and affects all of these factors and is therefore of paramount importance. Every industry is dependent upon engineering for capital plant and equipment; the quality of engineering design is therefore a major factor affecting costs and productivity in all industries including the engineering industries themselves.

There is evidence that the importance of design is not sufficiently appreciated by the managements of engineering businesses. The engineering profession has a lower social and economic status in Britain than in other highly industrialized countries. Technology attracts a lower proportion of the ablest school leavers than science and, of those who take engineering degrees and enter engineering industry, most are attracted by research and management appointments; very few take up design as a career.

Where the importance of design is appreciated and the design team is adequately staffed and given its proper status, British products are outstanding. The effects of the shortage of qualified and talented designers are, however, shown in the inadequate use made of new engineering knowledge in the design of some of the traditional products of British engineering industry. There is also disturbing evidence of failures resulting from a lack of attention to detail in almost all fields of mechanical engineering design. As rapid technological progress makes the task of the designer more complex, these weaknesses could become more serious. To remedy the situation, the Committee recommends that action be taken:*

(1) to impress upon the managements of engineering businesses the vital importance of the design function in engineering activity and the need to encourage more talented engineers to make their careers in design; 133 (i)

(2) to use all available means, especially television, to draw attention to the great importance of engineering in the national economy and to the urgent need for more able people to train as professional engineers and to make their careers as designers; 133 (ii) to (iv)

(3) to increase the prestige of design and the status of designers within the engineering profession and, where necessary, to amend the

* Paragraph numbers after each main recommendation refer to the Committee's detailed recommendations in the text of the report.

membership requirements of the Professional Institutions to give more prominence to design qualifications;

135 (i) to (iv)

(4) to encourage and co-ordinate experiments in methods of teaching design at undergraduate and postgraduate levels in universities and colleges and in industry;

144 (i) and (ii)

(5) to reorganize the practical training of professional engineers to include more emphasis on modern production methods, works organization, costs and the influence of design; and to bring about a closer integration of the practical and academic elements of education;

144 (iii) to (v)

(6) to ensure that draughtsmen and technicians who are concerned with detail design are given an adequate understanding of the principles involved;

144 (vi)

(7) to ensure that in the implementation of the scheme for industrial training described in the White Paper *Industrial Training: Government Proposals* (Cmnd. 1892) the industrial training of professional engineers and technicians as well as of skilled craftsmen will be included as soon as possible;

144 (vi)

(8) to establish institutes at suitable universities and colleges for advanced studies in particular fields of design in close association with industry; and to establish a higher degree in engineering design;

149 (i) to (vi)

(9) to encourage the further mechanization of draughting procedures using computer and other modern techniques so as to increase the productivity of designers;

151 (i) and (ii)

(10) to use development contracts to encourage the creation of design teams of high quality;

153 (i) to (iv)

(11) to use Government and public authority purchasing procedures to insist upon the highest possible standards of engineering design in the supplies and equipment produced for use in the armed services, civil establishments and the public sector of industry;

156 (i) and (ii)

(12) to encourage the Professional Institutions by means of grants from public funds to prepare and issue design manuals or " data sheets " similar to those already prepared by the Royal Aeronautical Society;

159 (i) to (iv)

(13) to ensure that British Standards always encourage and never inhibit good design practice; and

162

(14) to collect and publish information on the income and expenditure incurred under licence agreements between British and foreign firms so that the value of this trade can be assessed. 164

CHAPTER 1

INTRODUCTION

1. The Committee was formed by resolution of the Council for Scientific and Industrial Research at their meeting in May, 1962. The terms of reference for the Committee agreed by the Council were:

(i) to consider the present standing of mechanical engineering design in relation to the United Kingdom engineering industry and practice overseas; and

(ii) to recommend any changes which are likely to result in improved engineering design of British products, including, in particular, changes in education and training.

The Committee held its first meeting on 22nd June, 1962, and has since held twenty-one meetings of which ten were held for the purpose of hearing evidence.

2. On 12th July, 1962, the Parliamentary Under-Secretary for Science, Mr. Denzil Freeth, M.P., in the course of the debate on Science and Industry informed the House of Commons of the formation of the Committee and its terms of reference. As a result of the publicity given to this announcement the Committee received a large number of inquiries and offers of help. It became clear that there was a wide interest in the subject of the inquiry and that a number of people and organizations had made studies and held informed views. The Committee therefore decided that it should extend its inquiries sufficiently widely to give opportunity to all organizations which had an interest in the problem to submit their views. Invitations were therefore sent to professional bodies, to public and private industrial organizations, to trade unions, to Government departments and to educational institutions, and resulted in a most generous response. A list of the memoranda received appears in Appendix I. A list of those who gave oral evidence appears in Appendix II.

3. The Committee had in mind throughout its proceedings the injunction of the Research Council to work quickly and to report as early as possible. Although with the help of its witnesses it has been able to amass a considerable body of evidence on various aspects of the problems within its terms of reference, it has at no time aspired to be able to submit a final and definitive report on this subject. What it has tried to do is to analyse some of the problems involved and to suggest possible solutions. With this purpose in mind the Committee asked its witnesses to give evidence under four main headings:

(i) Evidence on the present standing or reputation of British engineering design as exemplified in British engineering products *vis-à-vis* competitors in world markets.

(ii) Evidence on the organization and status of engineering design teams in the various branches of British engineering industry.

(iii) Evidence on the adequacy of the supply and quality of design engineers and on the arrangements for their further education and training within industry.

(iv) Evidence on the adequacy or inadequacy of the courses in engineering offered by institutions of higher education to meet the needs of industry for engineering designers.

This evidence is discussed in some detail in Chapters IV and V of this report.

4. One meeting of the Committee was held in Scotland at which witnesses from Scottish industry and education gave evidence. The Committee also saw witnesses from Wales and Northern Ireland and concluded that, in their field, there were no special regional problems.

CHAPTER II

DEFINITIONS

5. Our terms of reference asked us specifically "to consider . . . mechanical engineering design." The words "design" and "designer" are used in several senses even within engineering industry. In view of the confusion of terminology, it was essential to provide for ourselves and for our witnesses, and ultimately for the purposes of this report, definitions of "mechanical engineering design" and of the function of the "mechanical engineering designer."

The definitions agreed were:

(i) Mechanical engineering design is the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform pre-specified functions with the maximum economy and efficiency.

(ii) The designer's responsibility covers the whole process from conception to the issue of detailed instructions for production and his interest continues throughout the designed life of the product in service.

6. The Committee's inquiry was confined to the field of mechanical engineering design and excluded civil, electrical and chemical engineering design as such. It was, however, agreed by all the Committee's witnesses that the faults and failures in structures and electrical and chemical plant were frequently attributable to bad mechanical design. It appeared, therefore, that the Committee's terms of reference must include the whole field of engineering production.

7. In some sectors of engineering industry the designation "designer" and the designation "draughtsman" were almost if not completely synonymous; in some firms the designation "designer" was reserved for senior draughtsmen, other designations being given to the engineers responsible for the initiation of the general plan of the solutions to the engineering problems posed by the specifications. Drawings are the usual means of communication between the designer and the user and between the designer and the production shops, though other means such as computer tapes may sometimes be used. All designers must, therefore, be good enough draughtsmen to be able to communicate, but it is by no means true that all draughtsmen are designers.

8. In inviting evidence we said that our inquiry was not concerned with appearance or styling. This statement has been criticized by some of our witnesses who rightly drew attention to the importance of appearance in selling any kind of goods, even capital equipment. It is possible, of course, that buyers of engineering goods do make aesthetic judgments and that these influence their choice, but as a Committee we felt that this field of speculation was excluded by our terms of reference. Our discussions of the importance of appearance of engineering goods confirmed us in our opinion that we were in fact dealing almost entirely with engineering values. When we heard criticisms that British engineering products looked "lumpish," "rough," "poorly finished," "old-fashioned," we found that almost always these offences to the eye could be traced to deficiencies in engineering design: lack

of knowledge of the properties of materials, inattention to detail, to the requirements of maintenance or to the convenience of the operator. British machines were being compared with foreign machines whose designers had understood better the refinements of design or the requirements of the user. While we may not go so far as to agree with the adage of the drawing office that " if a design looks right, it *is* right," the converse is almost certainly true.

9. Giving evidence on their work in engineering industry, the Council of Industrial Design said that " while dealing earlier primarily with appearance, industrial design is becoming progressively more concerned with the overall relationship between human beings and industrial goods. The industrial designer is tending to work in close collaboration with the ergonomist. . . ." The Council of Industrial Design is the body which has been most concerned with the appearance of British products and we consider that this statement of the Council is striking confirmation of our views on the relationship between good appearance and good engineering.

CHAPTER III

THE IMPORTANCE OF ENGINEERING DESIGN IN THE NATIONAL ECONOMY

10. Engineering goods are sold on the merits of their performance, reliability, appearance, delivery and price. Design, as defined by the Committee, determines most and affects all of these factors. The quality of mechanical engineering design is, therefore, a major factor determining the success of any business engaged in the manufacture of any sort of plant, machinery, vehicles, or instruments. In so far as engineering industry supplies plant and equipment to other industries, the quality of design is an important factor affecting the efficiency of all industries.

11. The engineering industries account for 35 per cent of the contribution of manufacturing industry to the gross national product and for nearly half of the United Kingdom's total exports. Exports account for about one-third of total engineering production.

12. Over the twelve years from 1950 to 1961 engineering production increased by 50 per cent and engineering exports by 33 per cent. The rate of growth in the engineering industries was faster than the rate of growth of the economy as a whole. Exports have increased faster than production since 1954 and accounted for a larger share of total exports in 1961 than they did in 1950.

13. These figures indicate the increasing importance of engineering industry in the United Kingdom economy and, while they show that there is at present nothing catastrophically wrong with British engineering, it is important to know whether the design resources upon which production and trade depend are adequate to sustain the higher rate of growth in the economy as a whole which the nation is now seeking to achieve.

14. The products of engineering industry meet the fiercest competition in export markets and the Committee therefore undertook an analysis of export performance to see whether this would provide any evidence on the comparative merits of the products of United Kingdom industry *vis-à-vis* the products of foreign competitors.

15. The analysis of trends in international trade in engineering products over the seven years from 1954 to 1960 showed that the British share of this trade had been declining. While British exports had been increasing, international trade had been increasing faster. More detailed analysis showed that the decline in the United Kingdom share of trade was spread over a wide range of goods including some of Britain's traditionally more important exports: ships, railway vehicles, agricultural machinery, textile machinery and metal-working machinery. There were, however, notable exceptions: in the field of prime movers (diesel engines, aero-engines, steam, gas, and water turbines) which was one of the fastest growing sections of international trade, United Kingdom exports increased faster than the total trade and in 1960 accounted for nearly 40 per cent of international trade in these goods. Up to 1959–60 the aircraft industry was also steadily increasing its share of the export market though its share has since fallen. Since 1955, the automotive industry has

maintained its share of trade in motor-cars and has considerably increased its share of trade in lorries and tractors.

16. Many factors other than design affect success in export markets. Tariffs, quotas, currency restrictions, credits and subsidies are beyond the control of the designer; so, to some extent, are wide differences in costs of labour and materials. There is little doubt that the high prime costs of American industry have been a factor in the decline of America's share of export trade in products in which she has not a clear technological lead or that the relatively low labour costs enjoyed until recently by Germany, Italy and Japan, have helped those countries to expand their foreign trade. While we do not ignore these other factors, we are not aware of any which explain the wide disparities in the export performance of different industries and firms. The buyers of aeroplanes, aero-engines, power plant and transport equipment (other than private motor-cars) are technically educated and experienced customers; if they buy British it is because the particular British design most nearly meets their requirements for performance and reliability at an acceptable price. "In the case of commercial vehicles and tractors," Mr. Maurice Platt of Vauxhall Motors Limited suggested, "the basic design is particularly important in its effect upon measurable operating results." Where British firms are consistently gaining on their foreign competitors, it must be attributed to the superiority of their design.

17. Conversely, we are obliged to conclude that if so many products, in which historically Britain excelled, are now losing ground in world markets, it is probably because the design of these products is failing to satisfy the customer. An examination of recent trends in imports of machinery lends some reinforcement to this conclusion.

18. In 1961 imports of machinery (excluding vehicles) were valued at £315 million. Imports cancelled out 28 per cent of exports of machinery (£1131 million) and represented a rise (at constant prices) of 224 per cent in the twelve years from 1950. These twelve years were marked by a progressive liberalization of trade and latterly by reductions in tariffs. Each step has resulted in a jump upwards in imports of machinery. During the three years 1960 to 1962 the domestic demand for textile machinery, machine tools, optical instruments and office machinery including computers, was met by more than 25 per cent from foreign sources. In relation to exports, imports may still be regarded as small, but we cannot regard with equanimity the increasing dependence of some British industries, and particularly British export industries, on foreign plant. Our direct costs of labour and materials are unlikely to be lower than those of our overseas competitors; if we rely on using the same machinery and manufacturing methods, we can have small hope of achieving any competitive advantage in final cost.

19. On 3rd April, 1963, *The Times* published an article by Professor T. Barna containing a highly relevant analysis of trends in the composition of United Kingdom foreign trade. This showed that compared with the United States and Germany, British net exports (exports minus imports) were relatively smallest in the most recently developed and technically most advanced products of industry like office machinery, scientific instruments, machine tools and plastics, in which international trade was growing fastest. Professor Barna concluded that "the inferior trading position of Britain is thus an indication

of technical backwardness." This provoked a correspondence in *The Times* on the causes and cures for the situation revealed by Professor Barna's analysis much of which reflected views which had already been submitted to us in evidence.

20. Statistical analyses have provided some factual basis for the more or less vague feelings of dissatisfaction with British mechanical engineering design which were current when the Committee was set up. The conclusion reached by the Committee from this evidence can be summed up in a statement by the Federation of British Industries that "the present standing and reputation of British engineering design is . . . generally good and in certain fields outstanding. We regard it, however, as certain that, if Britain is to conquer the proportion of a competitive world engineering market necessary to maintain our standard of living, quite drastic alterations will be needed to the present arrangements. . . ."

CHAPTER IV

THE PRESENT STANDING OF ENGINEERING DESIGN

(1) Technological initiative

21. Nearly all the evidence given to the Committee on the present standing and reputation of British engineering design as exemplified in British engineering products drew attention to the failure of particular sections of British engineering industry to keep abreast of foreign competitors in re-designing their products to take advantage of advances in technology. Machine tools, marine engines, textile machinery were frequently cited as products for which "the innovations of design have mostly come from other countries" (Amalgamated Engineering Union). Steel-making machinery, metal-forming machinery, printing machinery, leather-working machinery, railway equipment, agricultural machinery were also mentioned by one or more witnesses. All these products are traditional products of British engineering and the industries making them are old established industries. Several of them have been the subject of fairly detailed studies by D.S.I.R.

22. A review of the evidence on the subject of the lack of initiative in design suggested some of the causes which have contributed to the present state of affairs. The Committee was left in no doubt that in these older engineering industries, the traditional and standard designs were often excellent. Mr. C. C. Mitchell of Brown Brothers Limited, Edinburgh, thought that "companies with traditional products tended to rest on their laurels and that it was more difficult to improve the design of a successful article than to develop a new one." It is in fact not difficult to argue that the excellence of design and the high standards of production in the past were major contributors to the present difficulties. British machines were built to last and they have lasted only too well. Customers in the traditional markets were satisfied and when forced to buy new machines they inclined to seek the known and reliable rather than to embark upon novel experiments. Hence design development has been slow, proceeding by minor improvements and adjustments to the same basic designs.

23. In this environment it is hardly surprising that firms have, over the years, maintained their design staffs at the minimum level required to cope with the modest wants of their traditional customers. Now that they are being harried by new industries with new wants, by old industries with new problems and by official exhortations about exports and growth, they find themselves without the resources to take the new initiatives which are demanded of them and which many of the firms concerned would like to take. As Mr. Maurice Platt of Vauxhall Motors Limited remarked, "One ought to distinguish between creative inspiration and imagination which is an essential part of design and sheer professional competence reflected in the ease with which a product could be manufactured, its reliability, etc. Both types of design are necessary." But in some industries it is the first type which seems to be lacking.

24. Two other factors have contributed to this state of affairs. The spectacular development of new industries during and after the war, largely supported

by massive Government contracts, offered glamorous opportunities to bright young engineers and draughtsmen, which, even without direction of labour (in the war) and (later) higher salaries and apparently better prospects, would have made it difficult for the traditional industries to hold on to highly qualified engineers with original talent. The new industries were able to absorb a very large proportion of the available engineering talent and in the traditional industries even the most far-sighted firms who tried to recruit had little success.

25. The other factor which several witnesses suggested was important was the post-war sellers' market. Britain's industry was not destroyed by the war: much of Europe's was. Europe and some other parts of the world had urgent need to re-equip their industries and to replenish their transport equipment. British industry could supply and Britain had an urgent need to export. Consequently when military production ceased, civil production was got going as fast as possible using pre-war designs; old jigs and tools were brought out of store and old machines were adapted. Everything that was made could be sold, so why spend money on designing something new? All over the world the market for conventional machine tools, textile machinery, ships and vehicles was more than Britain could supply. There was little need to bother about new designs or about costs.

26. Our discussions with industry convinced us that there is a fairly wide understanding of the dangers for the nation as a whole, for particular industries and for individual firms, of allowing the resources for engineering design innovation to decline to a level which makes the industry or firm unable to match the iniative of their competitors. The extreme example is the case of the North British Locomotive Company Limited, which delayed so long in taking the necessary steps to diversify its production and to adapt its capacity to build diesel instead of steam locomotives, that when it was finally forced to make the change, it found itself with work people who had no tradition and little experience of precision engineering and a staff and labour who were still "steam-minded." Although licences for the manufacture of diesel engines were obtained, the delay in organizing effective production was fatal and the company went into liquidation.*

27. The high degree of dependence of some parts of engineering industry on foreign licences attracted the Committee's attention. Studies made by D.S.I.R. of foundry equipment, marine engines and some metal-forming processes drew attention to this feature. A review conducted by the staff of the British Iron and Steel Research Association revealed that a very large amount of modern steel-making plant is made under foreign licence. Many witnesses agreed that foreign licences were often sought as the alternative to the difficult and initially more expensive task of organizing a design team and supporting it with adequate research and development facilities. The arguments about the dangers of too great dependence on imported production equipment apply also to too great dependence on equipment made under foreign licence. There are also other objections. Licences normally limit the export franchise; they also usually include covenants about the feed back free to the licensor of details of modifications and improvements; they may even (though more rarely) include agreements not to engage in any independent research.

28. There are, of course, occasions when the buying of a foreign licence is an

* Statement from the Chairman to all Stockholders and all Creditors, 2nd April, 1962.

enlightened and justifiable first step towards the setting up of a new line of business which the firm in question intends to develop with its own research and development and design initiative. There is clearly no sense in doing again expensive research and development which has been done overseas and the results of which can be bought more cheaply for licence fees and royalties. In some industries extensive use is made of patented mechanisms and techniques which are incorporated into designs of equipment and systems which are themselves original. In these industries, which include the motor-car industry and the electronics industry, there is an extensive trade in " know-how " which should certainly not be discouraged. Nevertheless, the Committee feels that there are too many cases where the possession of licences inhibits design development to an extent which is detrimental to the national interest. It is a matter of the utmost national importance that an exporting country should export its own designs, rather than become dependent upon the ideas of engineers in other countries.

(2) Use of basic engineering knowledge

29. The process of making an engineering design can be divided into two main stages:

(i) the conversion of the customer's (or the marketing department's) specification into design requirements, the selection of a process or system capable of meeting those requirements and the preparation of general and sectional arrangement drawings;

(ii) the detailed design for manufacture of the components and mechanisms outlined in the arrangement drawings.

30. Sound basic engineering knowledge is required throughout both stages of the design process though it is at the first stage that there are opportunities for the designer to propose original solutions based on new knowledge. Some customers, notably those in manufacturing and service industries which employ qualified personnel to draw up procurement specifications, have fairly clear ideas as to their requirements and can supply data directly usable by the designers of the products they are seeking. But it has to be recognized that many customers, and particularly the buyers of consumer goods, cannot specify their needs in engineering terms. The farmer may need a machine for lifting potatoes without loss or damage to the tubers, the housewife a machine for washing, drying and ironing clothes, but neither has any idea of the mechanical principles which could be employed in devising a machine to comply with their requirements. At the first stage of design, therefore, the designer may have to exercise a very considerable amount of ingenuity and imagination in converting the customer's needs into design requirements and may even have to initiate research to determine these needs in sufficient detail to be able to formulate a mechanical solution at all. It is in circumstances where there is greatest scope for initiative that design talent is likely to show to best advantage. There was a considerable divergence of views among the Committee's witnesses about the quality of British engineering design at this first stage.

31. Some thought that it was usually good. Sir Christopher Hinton told us that in the field of process engineering design, the performance of design teams was now of a higher standard than in the past. This, he said, was because technically qualified engineers were now normally employed. An Admiralty witness said that " the design concepts produced by British industry to fulfil

naval requirements can usually match or better those produced in other countries for naval purposes." The Society of British Aircraft Constructors said that "the design, research and development teams in the aircraft industry continue to pioneer engineering technologies from which stem products well able to compete in quality and performance in the markets of the world."

32. On the other hand, some witnesses were critical: the Engineering Institutions' Joint Council suggested that design "tends to follow a pattern already established rather than breaking new ground." Sir Ewart Smith thought that "as a result of the shortage of good fundamental designers, and due to failure of many managements to appreciate the importance and proper status of design, the possibilities arising from much scientific work were not applied promptly or effectively. This was particularly unfortunate when the original research or invention had its origin in this country." The Committee of Directors of Research Associations cited particular fields in which they thought engineering designers lacked basic knowledge. These included fluid mechanics, the design implications of welding techniques and (outside the aircraft industry) modern methods of stress analysis.

33. Several witnesses drew attention to the fact that British designs were often heavier than those from other countries owing to failure to exploit up-to-date knowledge of the properties of materials and techniques of fabrication. The Air Ministry said that there was inadequate appreciation of what is required to ensure acceptable standards of reliability in complex equipment. We were disturbed to learn of the high cost of unreliability in the Royal Air Force—"maintenance makes up 50 per cent of the total cost of the Royal Air Force . . . spares alone cost £100 million per year." Although much unreliability can be attributed to poor detail design, Air Ministry and other witnesses emphasized the need to design for reliability at the first stage. We were told that "the aircraft industry must take steps to make itself thoroughly reliability-conscious at all levels." Such a consciousness will, we believe, become steadily more necessary in other industries as equipment becomes more complex.

34. On the whole, however, the evidence led us to conclude that, in the newer science-based industries, basic engineering knowledge is usually applied satisfactorily at the first stage of the design process. The work is carried out mainly by professional engineers who have had adequate training. In the more traditional industries qualified engineers are less numerous and less use has been made of modern technological developments, but there are welcome signs that in some quarters the position is changing. The Machine Tool Trades Association said that "there seems to be a growing tendency . . . to see that the chief designer is a mechanical engineering graduate having a seat on the Board with the right to play a significant part in developing overall company policy, and supported by a team with higher qualifications than has been the practice in the past." Representatives of the scientific instruments industry were very much aware of their industry's shortage of technically qualified people in research, design and management and described to us the arrangements that were being made with the Northampton College of Advanced Technology to provide special advanced courses in instrument design. They also showed us copies of a comprehensive handbook on instrument design which had been written and published following the work of a committee set up jointly by the British Scientific Instrument Manufacturers' Association and the British Scientific Instrument Research Association.

35. Unfortunately, some parts of industry continue complacently to pursue old ways. " It is, in our opinion, a matter for consideration as to whether such deficiencies as exist in British mechanical engineering products do not reside more in an inadequate standard of workmanship than in unsatisfactory design." " Engineering designs of the United Kingdom were considered to be no better and no worse than elsewhere." Such comments betray an uncritical attitude which will not result in those improvements in design and production which are essential for our economic survival.

(3) Detail design

36. While there is some divergence of views about the extent to which basic engineering knowledge is being applied in engineering industry at the first stage of the design process, there is almost complete unanimity about the frequently unsatisfactory standards of detail design. While it was not suggested to us that this was a peculiarly British problem, its economic implications are particularly serious for a country such as ours. Deficiencies in detail design can be and often are overcome by successive modifications and adjustments at the development stage when the prototype or pilot plant is being run and tested. This, however, adds enormously to costs which are difficult to recover, particularly in export markets, and absorbs the time of yet more qualified engineers who are in short supply. If deficiencies are not made good at the development stage but result in failures in service, the maker's reputation is likely to suffer disproportionate damage and, if the customer is an export customer, the damage may reflect upon a whole industry.

37. Discussing the design of process plant, Sir Christopher Hinton said that it was the standard of detail design that caused alarm. This type of design, he suggested, is best done by engineering designers who have served a five-year apprenticeship, a great part of this being spent upon the shop floor, and have reached the design office by promotion from the drawing office. He thought that the trouble arose from the fact that there were now not enough people who had had this training to staff detail design offices. The Institute of Marine Engineers hold the same view: " British engineering design suffers from a lack of attention to detail. . . . There is a shortage of well-trained and qualified engineering designers." Mr. J. M. Rollo of Rollo Industries Limited suggested that " In the main, British fundamental design is reliable but ignorance of practical requirements is too often displayed in the design of small items."

38. The Service departments gave much detailed evidence in support of the same general view. The Director of the Military Engineering Experimental Establishment wrote: " Many engineering designs which as a whole are sound, ingenious and possible even brilliant are spoilt by lack of attention to detail. This is often because the concept started by a fully-trained and experienced professional engineer, is finished off by staff with less wide fundamental knowledge and less originality." We have already quoted evidence from the Air Ministry of the high cost of unreliability to the Royal Air Force. " The primary cause of the high cost of maintenance is lack of designed-in-reliability and maintainability . . . analysis of defects shows that few are associated with the integrity of the main structure . . .. When bad design occurs it is found to be basically bad detail design." Poor mechanical design was also given as one of the prime causes of the high rate of failure in electronic equipment, both ground

and air-borne. Complaints concerning lack of reliability were reiterated by witnesses from all three services. An Admiralty witness concluded that most failures arose from faults in detail design.

39. The United Kingdom Atomic Energy Authority had similar views: "It has been the Authority's experience in carrying out large novel projects . . . that major successes have been achieved by critical attention to details, no less than by the thought and attention given to the original conception of the project. . . . There is a tendency for designs to be spoiled by lack of attention to detail and this often causes difficult and costly rectification work at site that could have been avoided by more rigorous thought at the design stage . . .." The National Coal Board commented that "An outstanding weakness in design arises from the failure to consider the problem of maintenance at the design stage." The Gas Council said: "A particular sphere where British design comes under criticism is that of operation and maintenance, and new equipment is often put on the market without sufficient attention being paid to the detail of these important aspects." Witnesses from the scientific instrument industry went so far as to agree that if British instruments were more reliable, more could probably be sold.

40. Two other failings were pinpointed in the evidence: failure of designers to take into account fatigue, and ignorance of welding. On fatigue and welding the Director of the British Welding Research Association wrote: "While neglect of fatigue might well be considered the most serious shortcoming of British engineering design, many failures are experienced, sometimes even before a piece of equipment goes into service, as a result of ignorance in relation to the problems arising in the application of welding. Very frequently welding is used in materials which are either totally unsuitable for welding or where, if they are welded, special techniques and precautions have to be employed." This is also the experience of the National Engineering Laboratory who find that neglect of fatigue is the basic cause of more than three-quarters of the failures in service which are referred to them.

41. The evidence left the Committee in no doubt of the concern felt by engineers throughout industry and Government establishments about the too frequent lack of attention to detail during the final stages of the design process. Many witnesses attributed this to a shortage of engineers with appropriate training in the detail design offices. While there is no doubt about the shortage of design engineers, the Committee concluded that the weakness of detail design offices could be attributed to a compound of three factors:

(i) The unwillingness of qualified design engineers to work on detail design.
(ii) The incomplete education and training of the draughtsmen and technicians who compose the staff of detail design offices.
(iii) A lack of appreciation on the part of management of the importance of detail design.

42. The Committe believes that there are occasions when the detail design office is not provided with sufficient information about the performance specifications which the design is required to meet. This can be due either to a failure on the part of those responsible for the general layout drawings to communicate enough information or to a failure on the part of the detail designers to appre-

ciate the information communicated. In either case, it is the responsibility of management to see that the design team work as a unity and that the customers' requirements are fully understood and properly interpreted. In design *everything* matters.

CHAPTER V

FACTORS AFFECTING THE QUALITY OF ENGINEERING DESIGN

(1) Attitudes of managements

43. There seems to the Committee to be a widespread view among managements of engineering businesses that design is something separate from management which can be carried out in a back-room. Many witnesses referred to the subordinate position accorded to the design office by comparison with the sales and production departments.

44. The Institution of Works Managers has said that the quality of management is the most important factor limiting business efficiency and the growth of productivity. We are convinced that this is true and suggest that ignorance of the true function of design and its importance in an engineering business is a major failing of many managements and a main cause of the deficiencies in British engineering design described in the foregoing chapter. Mr. Harold Smith of Imperial Chemical Industries Limited suggested that " In far too many cases there is a lack of forward thinking on the part of management which results in lack of incentive to develop new designs." Mr. L. H. Dawtrey, Past Chairman of the Automobile Division, The Institution of Mechanical Engineers, wrote: " The status of engineering depends on the outlook of the higher management and the managing director. All too frequently these consist of salesmen and accountants. Where engineers are at the very top ... the status of engineering is generally good." This view was reinforced by evidence we received from firms which had been outstandingly successful in design. In these firms there were engineers with design experience in top management, the design team occupied a central position in the staff organization, and had routine communication with the other departments. These firms had given a great deal of thought and effort to the recruitment, training and organization of their design teams and were able to give us much evidence on the problems they faced. Elsewhere, the effects of the general ignorance or neglect of the importance of design are shown in the poor organization of design teams, the low social and economic status of design staff and the consequent failure to attract well-qualified engineers into design work. These three aspects are discussed in the following sections.

(2) The organization of design in industry

45. The body of evidence summarized above on the neglect of or inattention to detail in design suggests that there is something wrong with the organization of the activity. The Committee's second question to witnesses was directed to obtaining evidence on the organization and status of design teams in the various branches of engineering industry.

46. It was fairly clear from the evidence that engineering industry had not for the most part accommodated itself to the post-war development of the educational system. Until this development got under way, the shop floor was the main point of entry into engineering and engineering firms relied on their apprentice schemes to supply them not only with skilled tradesmen, but

with their drawing office staff, design engineers and managers. All apprentices acquired the know-how of the shop floor, the brighter ones graduated to the drawing office and learned engineering drawing under chief draughtsmen who had spent their lives at the drawing board. By private study and attendance at night-school those with the intellectual ability acquired the necessary scientific and technical knowledge and, in course of time, worked their way through the drawing office to become designers. This system undoubtedly produced good engineers and its products are the main-stay of many firms. But they are a dying race.

47. The vast expansion of the educational system of the country now provides opportunities for further education for a much higher proportion of young men and women than heretofore. Such complaints as the Committee heard from industrialists about the quality of craft apprentices are not a reflection on the quality of the younger generation but a result of the success of the educational system. The clock cannot be set back; old-fashioned apprentice schemes cannot now be expected to produce engineers of quality; arrangements must be made to recruit older apprentices from secondary schools, colleges and universities and to give them appropriate training.

48. Simultaneously, with the revolution in education, there have also been major changes in engineering itself—changes brought about by the rapid rate of technological progress. The design of modern engineering products requires an amount of scientific and technological knowledge which can only be acquired through formal study. Recognizing this, industry has become increasingly dependent on the products of the universities and technical colleges.

49. The effect of these two trends, in the educational system and in technology, was described by Mr. G. S. Bosworth of the English Electric Co. Ltd., as follows: " Industry has reacted to these two trends by dividing the design function into at least two parts; one of these concerns itself with the scientific aspects of design . . . leading to the specification of limits which must be observed, but seldom defining how they are to be contained; the other concerns itself with depicting the shapes of the components within these limits. The first is frequently designated as an engineering department, the second as a design or drawing office. The manufacturing aspect of design—especially in large organizations, is frequently imposed subsequently by production engineers modifying the drawings and other forms of information to meet their requirements. Thus, the design process has changed from an individual to a very loosely co-ordinated team activity with most of the able people concerned with the setting of particular limits and not with the creative process of deciding the best final form of the finished product. . . ."

50. The Federation of British Industries, in their evidence, recognized the same division of function. " There are two factors in mechanical engineering design. The first is the technological aspect, which is concerned with the scientific and mathematical principles on which the design depends, the second is the mechanical design of the machine itself as an aggregation of parts (made of suitable materials) which can be manufactured economically, and which when made will be efficient, trouble-free, easy to operate and maintain, attractive in appearance, and which will have a certain life. Clearly the second aspect demands first-class ability in the individuals who determine the form of the product and, in our opinion, that aspect is already receiving insufficient

attention in British engineering. There are signs also that it is being provided by a small and diminishing population of elderly men whose successors are in many cases not visible."

51. The evidence leaves the Committee in no doubt that, with the exception of the newer and technologically most advanced sections (aircraft, atomic energy, power generation) mechanical engineering industry still prefers to train its own designers by the traditional route: an engineering apprenticeship followed by a long spell in the drawing office. The recruitment of graduate engineers and scientists, in so far as it takes place at all, is into other departments and particularly into research and development. The different breeds do not mix and this perpetuates the split of responsibility and function commented upon by our witnesses. Even in the aircraft and power-generation industries, the division of function is difficult to bridge because, although there are many more graduates and they are more extensively used, design offices are still generally recruited and organized in the old way.

52. The United Kingdom Atomic Energy Authority, Rolls-Royce Aero Division, and several other large modern engineering undertakings described to us the enormously complex organization which is now necessary for the adequate performance of the design function. The day has now passed when it was possible for one man to command a sufficiency of knowledge and skill to take sole charge of the entire process of design and the complications inherent in the organization of a team have replaced the stark simplicity of a dictatorship. It is, however, the Committee's firm conclusion that the design function cannot be divided and that the attempt to run engineering businesses with split responsibility for engineering matters is the main cause of the design faults in the products to which so many witnesses drew attention.

(3) Status of design staff

53. Almost all the Committee's witnesses had something to say on the subject of status and almost all agreed that the economic and organizational status accorded to engineers engaged in design was generally low by comparison with the status accorded to other staff employed in their professional capacities. Consequently, too few people with creative talent were attracted to design; of those who were recruited into design offices, most sought the first opportunity to transfer to other branches of activity such as development, sales or management. The main exception was the aircraft industry where, according to Sir George Edwards of the British Aircraft Corporation Limited, "The status of design staff in relation to other specialist staff is generally good . . . probably because of the major role they play."

54. The terms "draughtsman" and "designer" appear in some industrial circles to be treated as synonymous. The social and economic status of draughtsmen has apparently declined and is such at the present time that recruitment of people of adequate ability presents difficulties. It is not uncommon for firms, in an effort to enhance the status of the drawing office, to award the chief draughtsman the title of chief designer and to call senior draughtsmen designers although in fact they may not be carrying the full responsibilities for design. In any case, most of the older men in drawing offices have come up the old way through apprentice schemes and their activities are guided to a large extent by drawing-office lore. They do not easily absorb young recruits from the universities and colleges who have

received an amount of scientific education incomprehensible to the older man, but minimal amounts of shop-floor experience. All sorts of factors tend to vitiate the relationship. The young graduates have, or are thought to have, airs and graces and to think themselves superior to those who have not had their educational advantages. They are ambitious and impatient and tend to despise the value of experience. Very often they have not learnt to draw and as draughtsmen their work is inferior to that of men of the same age who served apprenticeships instead of going to the university. Promotion through the drawing office is slow, there appear to be few opportunities to use their education, and life in other parts of the organization looks much more exciting and profitable. They seize the first opportunity to leave the drawing board —before, probably, they have learnt to draw or to appreciate fully the importance of the draughtsman's function.

55. The Committee is indebted to the Draughtsmen's and Allied Technicians' Association (D.A.T.A.) for a detailed memorandum of evidence on this whole subject. The Association confirmed that there is a widespread feeling among its members that they occupy a subordinate position which does less than justice to the importance of design for British industrial progress, that they are regarded as a necessary but expensive overhead. The fact that the controlling positions in many big engineering firms are occupied by men with a financial and commercial background rather than with technical or scientific training contributed to this feeling; so did the traditionally subordinate position of technology in the British educational system.

56. There has been an increasing tendency to look outside the design offices for the new ideas. If the status of design has declined, it is quite certain that the status of research and development has increased. Research is now a prestige activity, attracting the best scientific and technological brains. The prestige, of course, largely and quite justifiably derives from the spectacular success of organized research effort in maintaining and accelerating technological progress. But the glamour and respectability now commonly attached to research seems to have diverted attention from the fact that only via design can the results of research be translated into products for the benefit of society.

57. Research departments have acquired a status in engineering industry which is denied to design. They receive special tax treatment, are cherished by managements, offer good salaries and prospects to graduates and are regarded by the élite of university departments of science and engineering as a respectable alternative to a career in university research.

58. Evidence on salaries of engineers generally, published by the Engineers' Guild, and of design staff in particular, supplied by D.A.T.A., supports this general impression of social rating. The Draughtsmen's and Allied Technicians' Association stated that the "career expectation in material rewards for engineering design staff is poor. . . . The average wage, without overtime, of all draughtsmen aged over 30, calculated by D.A.T.A. from its annual statistical survey, is about £1000 a year." The detailed statistical evidence supporting this statement also showed that the average salaries of design-office section leaders in 1961 ranged from about £1000 a year in general engineering to £1300 in chemical engineering.

59. D.A.T.A. also drew attention to the positive disincentive of the design-office salary structure to the recruitment of design staff—" At the age of 21 . . .

when a young man normally completes his apprenticeship, he is entitled to the full rate as a craftsman in the workshop. He will almost certainly earn considerably more if he chooses to remain in or return to the workshop than if he chooses to enter or to remain in the drawing office. The average wage of drawing office staff at age 21 at the end of 1961 was just under £12 for a basic week of not more than 38½ hours. A craftsman in the workshop would probably earn at least £2 more than this for a basic week of 42 hours. In many firms the difference would be greater."

60. The Survey of Professional Engineers' Income 1959/60 carried out by the Engineers' Guild does not give separate information about the incomes of design staff and its chief interest lies in the evidence it provides on the salary prospects of professional engineers. In 1959/60, 96 per cent of all professional engineers were receiving salaries of less than £2000 per annum. Information collected by Associated Industrial Consultants and published in *The Economist* 12th January, 1963, showed, in a comparison of median salaries of senior executive staff in industry, that chief engineers ranked below company secretaries or chief accountants, works managers, sales managers and research executives. There is evidence that the salary prospects of professional engineers in other industrially advanced countries are relatively better.

61. The Engineers' Guild Survey also provided evidence that, on average, graduate engineers' salaries were slightly higher than non-graduates' and that the differentials increased in the upper age groups. This last point, though interesting, may only reflect the fact that proportionaly more graduates than non-graduates find their way to higher management.

62. Economic rating and social rating are obviously closely allied. Professor S. P. Hutton of the University College of South Wales and Monmouthshire in his evidence described a survey which had been made by the College in which a national cross-section of the public were asked to rank ten occupations in order of their status. The occupations and the order in which they were rated were:— doctor, solicitor, university lecturer, research physicist, company director, dentist, chartered accountant, *professional engineer*, primary school teacher and works manager. The results of other researches in this field published in the *New Scientist* 31st January, 1963,* provided additional confirmation of the low social rating accorded to engineering by the British public and more significantly by sixth-form schoolboys.

(4) Recruitment of design staff

63. There is an acute shortage of professional engineers and technicians in relation to industry's need for them. Successive Surveys of Scientific and Engineering Manpower carried out by the Ministry of Labour for the Advisory Council on Scientific Policy have drawn public attention to the persistent shortage of engineers and technologists which affects industry as a whole and bears more heavily on some of the old-established sectors of engineering industry than on the new science-based industries. Forecasts of the longer term demand for and supply of scientists and engineers, also carried out under the auspices of the A.C.S.P. suggest that the shortage of engineers is likely to persist longer than the shortage of scientists. It seems probable that the shortage of supply is being aggravated by the social influences, described in the last

* Also in *Engineering* 1st March, 1963.

section, which cause a higher proportion of the ablest school-leavers to opt for science rather than for engineering. Many professors of engineering told us that some places for engineering students in colleges and universities remained unfilled, and that others were filled by students who had failed to make the grade in mathematics and science departments.

64. We believe that the prestige of the universities in Britain ensures that a high proportion of those who are able and willing to study engineering at a university now in fact do so. The returns collected by the A.C.S.P. and published in their annual reports show that of approximately 2500 mechanical engineers qualifying each year, about 20 per cent are honours graduates. In 1960/61 an additional 3 per cent were holders of the Diploma in Technology.

65. The only statistical evidence on the distribution of graduate and non-graduate professional engineers between the different engineering functions in engineering industry was provided by the results of a research carried out by the University College of South Wales and Monmouthshire under the direction of Professor S. P. Hutton and financed by a D.S.I.R. grant. Professor Hutton's team interviewed a sample of 977 members of the Institution of Mechanical Engineers. The normal distribution of university graduates in the membership of the Institution was found to be 22 per cent; for purposes of analysis the proportion in the sample was increased to 40 per cent. In the total sample of 977 engineers 36 per cent had never worked in a drawing office, and 50 per cent of the graduates had never done so. Analysis of present employments showed that 8 per cent of the graduates and 19 per cent of the non-graduates were employed wholly on design. Weighting for normal distribution showed that 90 per cent of the designers were non-graduates. The survey also revealed that of 110 engineers interviewed who earned more than £3000 a year, none was employed on design; of the 300 earning between £1800 and £2900 a year, 8 per cent were designers compared with 47 per cent in management.

66. The engineers from industry who gave evidence to the Committee were fairly evenly divided between those who thought that good designers could best be trained through the traditional apprenticeship arrangements, and those who thought that graduate engineers would make even better designers if only they could be persuaded to take up design as a career. All agreed that the recruitment of designers through either route was becoming more, not less, difficult and that the greatest difficulty was to keep really good engineers in design offices.

(5) Education and training

67. Our terms of reference invited us to recommend any changes which are likely to result in improved design of British products, including, in particular, changes in education and training. We therefore invited evidence as widely as possible on the adequacy or inadequacy of the courses in engineering offered by institutions of higher education to meet the needs of industry for designers. We wrote to all universities and university colleges in Great Britain with engineering departments and received replies from almost all. We also wrote to all colleges of advanced technology in England and Wales and colleges of similar status in Scotland. In all, nine of these colleges replied. We received a Memorandum of Evidence in the joint names of the Ministry of Education and the Scottish Education Department. The National Council for Technological

Awards, the Association of Teachers in Technical Institutions, the Association of Technical Institutions and the Association of Principals of Technical Institutions also gave evidence.

68. There was one common theme in all this evidence: an awareness of the shortage of talented engineers in relation to industry's need and of the particular shortage of talented designers. It was almost universally assumed that the institutions of higher education both should and could do something to remedy the shortage. Beyond this point, however, there was no common view.

Teaching design at undergraduate level: views of witnesses

69. The subject of teaching design, whether it can be taught, how, where and when it should be taught, is being widely discussed among engineers in industry, and in the universities and colleges. Changes are being made in curricula and experiments with new combinations of subjects and new methods of teaching are being carried out. In most cases, the changes and experiments are of relatively recent date and it is too early to judge the results.

70. The evidence showed that institutions of higher education are faced with three principal difficulties:

(i) As already discussed in the foregoing sections, the engineering departments attract a smaller proportion of talented students than the science departments.

(ii) Although industry complains about the graduates it recruits, it has so far failed to produce any clear specification of the qualities and qualifications it looks for in the young designer. Universities and colleges are, therefore, left to decide upon the content of education which is most likely to be serviceable to their students in their careers (not all universities are content to guess: two, at least, have undertaken research to help them reshape their courses).

(iii) Universities and colleges have inherited a dual function in teaching: their main function is to *educate*, but they are also expected by society to *train* students for particular careers. While it is undoubtedly possible to give students in a three or four year course a fairly thorough education in engineering principles, it is by no means certain that this education can include a sufficient element of training to turn out a man acceptable to industry as a " mechanical engineering designer."

71. On the difficulty of deciding upon the content of education, the University of Glasgow said: " Some of the difficulty experienced in formulating plans for the new undergraduate course in engineering design has been due to the lack of any appreciable study of the methodology of the subject as it occurs in different branches of engineering. It is believed that there is an urgent need for research in this area if the best use is to be made of the current lively interest in the quality of engineering design in industry to improve the educational effort." The Royal College of Science and Technology also confirmed that " The qualities industry want in their designers or potential designers are very difficult to find out. Some central body from industry is required which can investigate this problem . . .." Industry's difficulties may of course derive from unwillingness to abandon the search for the unattainable. "Quite literally", wrote Professor R. E. D. Bishop of University College London, " the conflicting standards of perfection that a designer may be asked to aim at are those of

infinite life, no cost, no mass, no size, Carnot efficiency, extreme beauty, no time to design or make!"

72. It is possible that the confusion between education and training is at the root of the apparently conflicting views put forward by educationalists about the possibility of teaching design at the university. At the one extreme, Professor L. J. Kastner of King's College, London, held that " Mechanical engineering design requires the application of scientific principles to the solution of mechanical problems. It is therefore a scientific discipline, and it can be and should be taught in universities and technical colleges." At the other, Professor E. W. Parkes of Leicester University said that " It is not the universities' job to produce designers: it is our job to produce the kind of men that industry, if it does its part well, can turn into the designers that it needs." The views of industry, as given to the Committee, were equally conflicting. Mr. C. C. Mitchell of Brown Brothers Limited thought that " There was a need for training more designers at the undergraduate rather than postgraduate level; specialized training was best given within the company." Mr. A. Issigonis of the British Motor Corporation Limited said that " The craving to design exists from a very early age if it exists at all. It can be encouraged by the right sort of environment but only hindered by traditional higher education."

73. Among those in whose opinion some design should be taught at undergraduate level, there was again a divergence of opinion as to how to set about it. Aberdeen University thought that the elementary parts of the subject could be satisfactorily taught by lectures and that the more advanced treatment might be improved in two ways: (i) by members of staff returning to industry as practical designers for short periods; (ii) by experienced designers coming from industry for short periods or to hold seminars. Professor Sir John Baker of Cambridge University remarked upon " the danger of a system, often advocated in mechanical engineering circles, of having design in educational institutions taught by designers from industry. This system has been largely followed in the technical colleges which provide the men for the design staffs of the main constructional firms with the result that the same methods and the same prejudices were taught generation after generation. . . ."

74. Similarly opposed views appear in discussing the importance of engineering drawing in undergraduate study. Dr. D. G. Christopherson of Durham University suggested that " The designer must have a general plan . . .; he must then work out what is required in terms of materials and manufacture . . . and then he must put the whole thing down on paper, usually in a drawing. . . . It seems to me that most university programmes turn this process upside down. They start with the technique of communication, the drawing, before the man has anything much to say." Many of our other witnesses, on the other hand, laid down as axiomatic that students embarking upon a course of mechanical engineering design must be properly grounded in engineering drawing.

75. The difficulties of teaching design at undergraduate level were summed up by Professor Sir John Baker in his written evidence in which he said: " While experiments are continually being made in universities to teach design with, from time to time, small and temporary success, it is unrealistic to expect academic institutions to provide the whole mass of students with proper instruction in design. The reasons for this are many. The most serious is that it is impossible to reproduce in an academic atmosphere the conditions which

must exist for the process of design to have any reality. The essence of all but the simplest problems is the number of imponderables; the data available are on the one hand incomplete and on the other redundant. The designer must use judgment in the selection of data and the young student seldom has the experience on which to base rational decisions. Most of the attempts that have been made to overcome these difficulties in a class room so emasculate the problem that the bright student becomes bored. . . ."

76. Support was lent to Sir John's views by the results of a research which was carried out at Cambridge with the help of the Nuffield Foundation to identify and evaluate the knowledge and the skills which designers in industry must deploy in the fulfilment of their proper function. Only some of the knowledge and less of the skills were of a kind which could be imparted to a student in an academic institution. The rest could only be acquired in industry itself.

Engineering education and training in other European countries

77. The Committee was provided with a considerable amount of information about the arrangements for the education and training of engineers in other countries. The two main features in which continental arrangements differed significantly from British were:

(i) the relatively larger supply of qualified candidates for higher education in engineering and the relatively larger out-turn of qualified engineers;

(ii) the generally longer duration of courses leading to professional qualifications in engineering.

78. We believe that the first of these features reflects the different social attitudes in these other countries rather than the particular characteristics of educational institutions and that the latter derive their prestige from the prestige accorded by society to the engineer and not the other way round. We noted that in most European countries engineering is not a university subject and that higher education in engineering is provided by separate institutions which though generally ranking with universities are not themselves universities.

79. In France the education of engineers is provided in a variety of engineering schools falling broadly into three groups :

(i) The *Grandes Ecoles*, entry into which is by competitive examination after completing a two-year compulsory post-baccalauréat education which places heavy emphasis on mathematics and usually includes some physics and chemistry. A *Grande Ecole* course lasts three or four years. The *Grandes Ecoles* fall into two groups, those that give a general education, and those related to a particular branch of engineering. A student may go on from the former to the latter.

(ii) The *Ecole Nationale Supérieure d'Ingénieurs Arts et Métiers* which produces about half the mechanical engineers who qualify each year in France. The standard of entry is lower than for the *Grandes Ecoles*, calling for only one year of post-baccalauréat education. The courses follow the same pattern as those for the *Grandes Ecoles* but their aim is to produce engineers to work in the production rather than in the research or the administrative departments of industry. The course lasts four years, the first three of which include

a large element of drawing office training, and the fourth year includes 160 hours of design office work.

(iii) Adult education, whereby people at workshop or technician level in industry with a baccalauréat or equivalent can qualify as production engineers. The *Conservatoire National des Arts et Métiers* offers extremely arduous evening classes and the course may take as long as eight years. Private industry has set up a few schools administered on a co-operative basis by the firms interested which give a full-time two-years' course.

80. In France, no attempt is made to produce design engineers as such but all courses incorporate enough design study to enable the new entrant into industry to work in a design office. Nevertheless, the Director of the *Association pour le Développement des Techniques de l'Industrie Mécanique* (A.D.E.T.I.M.) has criticized the propensity of newly qualified engineers to produce impractical designs and to demand impossibly close tolerances. These faults arise, in his view, not from the system of education itself but from the habit of industrial employers of placing young engineers in design offices without giving them at least several years of workshop experience.

81. In view of this criticism we were interested to learn of two new institutions which have been established in close association with A.D.E.T.I.M. but under the Ministry of Education and the *Institut Supérieur des Matériaux de la Mécanique Industrielle*. The *Centre d'Etudes Supérieures de Technique Industrielle* offers a " sandwich " type of training extending over three years of which a total of one year is spent in industry. In their final year students are given actual current industrial problems to study and are expected to produce a workable answer. We were told that the methods of this school (still small) are beginning to be copied elsewhere in France. Linked with it are the *Cycles d'Etudes Supérieures de Mécanique Industrielle* which are seminar-type specialized refresher courses for engineers in mid-career.

82. In Germany, the education of professional engineers is carried out in the *Technische Hochschulen*. The average duration of the course leading to the qualification of *Diplom-Ingenieur* is six years. This includes 52 weeks supervised training in an engineering works, of which 26 must be undertaken before the student is accepted for the academic course. During the first three years the course follows much the same pattern as the B.Sc. course in British universities except that greater emphasis is placed upon engineering drawing than is general in this country. During the remaining two years the schedule of lectures is reduced and the student is required to make two or more fairly complicated design studies which take approximately six months each.

83. There is no doubt that the *Technische Hochschulen* turn out highly qualified engineers who serve German industry well. Nevertheless, the research director of a large German engineering company was reported to us to have said that what the students had learned in the way of design in the *Technische Hochschulen* was worth practically nothing and they had to learn again from the beginning when they joined the firm.

84. Several members of the Committee and many of our witnesses were familiar with the arrangements for educating and training engineers described above and with the corresponding institutions in Switzerland, the Netherlands,

Denmark and several other countries. We found that some, but not all, of the British educationalists to whom we talked considered that the longer courses required by continental institutions were in their favour. In view of this fairly unanimous opinion, we were interested to hear of a study made by a very large international company of the performance of engineers in their employment educated respectively in the United Kingdom and on the continent. It was found that class for class the British engineers reached a given salary bracket about three years younger than the continental ones, the difference being approximately equal to the difference in the length of their university courses.

The need for a change of emphasis in British engineering education

85. Our main criticism of engineering education in the United Kingdom does not relate to the length of courses, nor, particularly, to their content, but rather to the emphasis given to research rather than design as the objective. It is probably right that the ambitious young scientist should be directed towards research and that his teachers should engage in this activity when not teaching. In consequence the rating of science teachers and their promotion prospects tend to depend upon their achievements in research. This bias of scientific education has spread to the university engineering departments and from them to the colleges of advanced technology. Teachers of engineering subjects in universities and colleges engage in research or aspire to do so and students naturally emulate their mentors. Only rarely, in universities, are students encouraged to regard their studies as preparatory to a career in industry as designers and producers of goods.

86. It is therefore not so much a question of " teaching design " in universities and colleges, as of inculcating a different outlook among teachers and students on the uses to which their education may be put. In particular, if students are to become designers, they must be given, and know that they are being given, the intellectual tools for a creative activity, and they must somehow be encouraged to acquire a taste for this activity.

87. The function of a course at university level should be to give the engineer an adequate grounding in the basic scientific principles applied in engineering, to teach him scientific method, to develop his critical faculties and to make him aware of the kind of problems he will face as an engineer. Experience in the United States of America has shown that the attempt to treat engineering as a branch of science in university courses has not been successful in producing engineers for industry. Scientific problems are assumed to have single solutions; the solutions to engineering problems are almost always compromises. While the engineering student must learn the methods of scientific analysis, he must also learn something of economics and of production methods which enter into every practical engineering problem, and develop a faculty for improvization and invention.

The need for practical training and experience

88. After much discussion, the Committee reached the conclusion that it would be possible to inculcate a different approach to engineering studies only in students who had had previous experience in industry. Some elementary knowledge of production methods and of the use of the product, as well as of principles, is necessary before a student can start to design even the simplest mechanism. Until he can design something which can be produced

and made to work, he will not experience the satisfaction of creative activity nor see the relevance of his academic teaching.

89. We are, therefore, strongly in favour of the "sandwich" course leading to a first degree or Diploma in Technology for engineers destined to be designers. The advantages would seem to be with the colleges of advanced technology and other technical colleges running Dip. Tech. courses which already insist on the "sandwich," but we see no reason why university engineering departments should not also insist on a six to twelve months period in industry as a qualification for entry.

90. In advocating some form of "sandwich" course, as the most suitable undergraduate education for designers, we are advocating nothing new. Other authorities have reached the same conclusion, including the National Advisory Council on Education for Industry and Commerce, and the National Council for Technological Awards. There is, however, one aspect which we do not think has been given sufficient attention in this country: the planning and supervision of the periods spent by students in industry.

91. In their evidence the Federation of British Industries said: "When sandwich courses for the Diploma of Technology were introduced, the understanding was that industrial training would be complementary to academic studies. The whole aim of the scheme seems now to have been lost through the nature of the examination course." The evidence of the National Council for Technological Awards made it clear that the integration of academic study and industrial training has always been, and still is, one of the fundamental features of courses leading to the Diploma in Technology. While there are interesting developments towards this integration, its potentialities are far from being fully exploited at the present time. One consequence of this is that Dip. Tech. courses in common with other undergraduate courses tend to be based on an analytical rather than a synthetic approach. The examination system consequently tends to be used mainly to find out what the student has learnt at college and to test his powers of analysis. It is also relevant to quote the evidence of the University College of South Wales and Monmouthshire: "Too often graduates are put on to routine work in a mediocre design unit and are thereby discouraged at the outset from ever becoming designers. We try to correct this impression but many (about 30 per cent) of our students have either been apprentice draughtsmen or have spent a year in a design office when finishing their time and have no desire to return to design work."

92. In Germany, the activities of students undergoing training in industries are laid down in detail by *Technische Hochschulen* regulations which have the sanction of the Federal Government and are closely supervised at all stages. In this country the industrial training of students is left almost entirely to the discretion of the individual firm. Evidence given to the Committee indicated that some firms took immense trouble, while others were content to let the students fill in time watching other people work or performing unskilled jobs. That we heard of students being bored and frustrated by this experience is hardly surprising.

93. It is necessary to add that the blame for wasted time in industry does not lie solely with the employers. Not all colleges have yet made proper arrangements to keep in touch with their students during their spells in industry and none, so far as we know, examine them on what they have learned or otherwise

satisfy themselves that the time has been spent profitably. We understand that the colleges of technology are taking active steps to improve their arrangements, but it is not generally accepted by university departments that supervision of industrial training should be part of their responsibility.

94. There is clearly a need for more co-operation between employers and college authorities to develop the industrial "layers" of the "sandwich" into something really useful to the student.

95. Proper arrangements for the training of students working for degrees or Diplomas in Technology must place a considerable burden on even the largest engineering firms. It is well known that those which have proper arrangements and take trouble about their apprentices are in fact providing a free service to the rest of industry. A paper submitted to us by Sir George Edwards was outspoken on this subject: "The high cost of industrial training of young people (including wages of the apprentice) is a strong disincentive to training of adequate numbers, particularly as this cost is not uniformly shared and neither does the employing company necessarily retain those it trains. Some means is needed of sharing the load, e.g. by levy on all employers to subsidize those undertaking training, or by financing from public funds."

96. At an early stage of our proceedings we were told about the French arrangements for industrial training and of the *Taxe d'Apprentissage*. The tax is levied on pay-roll and the French Government supports apprentice training schools and other arrangements for industrial training of craftsmen, technicians and technologists. Firms which run their own apprentice schemes to approved standards are exempt from the tax, but in order to obtain complete exemption they must make provision for the different levels of training in the proportions which are laid down for the industry to which they belong. We had already discussed the possibility of introducing such a scheme into United Kingdom industry when the White Paper, *Industrial Training : Government Proposals* (Cmnd. 1892) was issued in December, 1962. We hope that the proposals in this paper will be applied as soon as possible to the industrial training of technicians and professional engineers as well as skilled craftsmen.

Teaching design at postgraduate level

97. So far we have discussed only undergraduate education and training and, in so far as every engineer must have a proper appreciation of the importance of design and learn to exercise his critical faculties, we have really been giving our views on the education of the engineer. The holder of a B.Sc. or a Dip. Tech. will still not be much use as a designer however keen he may be. There is such a vast variety of end products in engineering industry that training in design must almost certainly be particular rather than general.

98. There are some brilliant individuals who can tackle any engineering problem from first principles and offer a viable solution, but for the majority the opinion offered by the Machine Tool Trades Association is likely to be true: "Experience of manufacturing methods for a particular type of product and of its use is essential if a viable design is to emerge." The same point is made succinctly, if with some exaggeration, by Professor R. E. D. Bishop, who suggested that "a man who has spent years designing machine tools would probably design a bicycle which looked like a milling machine." On the whole, the evidence on the organization and staffing of design teams which have designed products of

internationally acknowledged excellence confirmed the view that the degree of specialization required would make it difficult to use the same team to design a product for a totally different application. A " mechanical engineering designer " is nowadays a rarity and we are in the main faced with the problem of training specialist designers in a whole range of different fields.

99. As the Ministry of Education and the Scottish Education Department suggested in their evidence, the teaching of engineering design must in the main be concentrated at postgraduate level. The difficulty is, as the Federation of British Industries pointed out, that " postgraduate courses in design have so far failed to recruit sufficient numbers . . . and the candidates have not been of really first-class calibre." Several other witnesses, including the Ministry of Education and the Northampton College of Advanced Technology, gave us examples of postgraduate courses which had been offered recently but had had to be withdrawn or postponed because insufficient numbers of students applied. Mr. C. C. Mitchell suggested that " . . . the introduction of a one-year postgraduate course leading to a master's degree in advanced design techniques would improve the quality of designers, but it would be difficult for a company to release men doing responsible work for a course of this duration." There are, however, two examples where postgraduate courses in design for particular sections of industry have been notably successful. In each case the course is a two-year full-time postgraduate course, the one is related to the needs of the aircraft industry and the other to the needs of the machine-tool industry.

100. On the first, the Ministry of Education states: " the most substantial contribution by a college within the Ministry's purview is being made by the College of Aeronautics [at Cranfield] which provides a two-year course in aeronautical design that is strongly supported by the aircraft industry." In their evidence the Society of British Aircraft Constructors say that " the Society is convinced that for the British aircraft industry to maintain its natural technical development and meet the intense competition for world markets a fundamental requirement is a soundly conceived, expertly managed, and progressive training programme." In the Society's arrangements for training, Cranfield plays an important part: " On satisfactory completion of an apprenticeship training within the aircraft industry, selected young men are encouraged to continue their studies in aeronautical engineering subjects, and the Society's Postgraduate Scholarship Scheme enables apprentices of outstanding ability to take two-year postgraduate training at colleges of advanced technology and other colleges offering appropriate courses."

101. In their evidence the Machine Tool Trades Association told us that, recognizing the need for a new approach, the industry some years ago took practical steps to expand education in machine-tool design. What was required, they discovered, " was a much deeper and more extensive knowledge of fundamental engineering sciences and the development of design ability, fostered in a truly academic environment." After full study of various alternatives a two-year full-time course was promoted at Manchester College of Science and Technology under the direction of Professor Frank Koenigsberger. To support this course the Association awards ten scholarships a year, each of two years' duration. " So far forty scholarships have been awarded. Most of the candidates had previously only had the opportunity of part-time education (although some had graduated at university or by full-time technical

college courses); for them, the two-year period in the university has been a valuable educational experience; their employers have been most impressed with the evidence of its broadening influence upon their characters and approach to their work in industry.

102. " Too often in British industry generally, designer-draughtsmen have been brought up in a relatively narrow environment, having spent their lives from apprenticeship in one or two firms. An essential feature of our scheme, intended to counteract this fault, is that each scholar is required to work during the first summer vacation for a machine tool manufacturer engaged in producing a type of machine tool altogether different from his previous experience. Furthermore, during the second and last summer vacation, scholars spend two months working in the design offices and works of machine-tool manufacturers in continental Europe."

103. The Committee was very favourably impressed by the solutions to the problem of training designers evolved by the College of Aeronautics with the Society of British Aircraft Constructors and by the Manchester College of Science and Technology with the Machine Tool Trades Association. Other industries should be encouraged to make similar arrangements with appropriate universities or colleges of technology to establish courses planned and staffed to meet their special needs and to undertake some real responsibility for seeing that the courses are adequately supported. We think that the success of the two schemes we have described has depended as much upon the initiative of the industry, the availability of scholarships and the responsible selection of scholars as upon the high quality of the teaching and the enthusiastic co-operation of the participating colleges. It is becoming increasingly necessary for industry to assist in education as well as in training. Sir George Edwards commented that " the state of the art in the more advanced branches of engineering is moving so rapidly that the staffs in the universities and technical colleges are having great difficulty in keeping abreast of current research and development." Mr. Maurice Platt of Vauxhall Motors Limited suggested: " one of the best ways of encouraging design studies would be to have senior people from industry giving lectures to local technical colleges. . . . " In spite of the difficulties, he said, " people from industry should contribute to education."

The education and training of technicians for design

104. Although the education and training of professional engineers for design is important, the education and training of supporting staff is no less important. In their evidence the Association of Teachers in Technical Institutions said: "We consider that the supply of technicians is a most urgent, and possibly a key problem. It seems to us that the technician is a critical link in the design team. He will be responsible for the bulk of the work in successfully implementing designs. The number of competent technicians required is very large. Many technicians carry considerable responsibility, are little short of the professional engineer in ability, and have a high degree of control in industry."

105. The evidence already discussed in Chapter IV on deficiencies in detail design suggests that the draughtsmen and other technicians who are responsible for detailing are often, for one reason or another, insufficiently informed of the principles involved in the design and of the service conditions it is required to meet. This can, of course, be due to bad design at the first stage of the design process or to failure of communications within the design team; but it may also

be due to the inadequate education and training of those in charge of the detailing office. The Association of Teachers in Technical Institutions thought that education and training was an important factor: "We feel that existing technical courses and training schemes are quite deficient in providing for the formation of effective design teams, or in encouraging the right attitude of mind." The Draughtsmen's and Allied Technicians' Association said that they had "always opposed the recruitment of persons without an adequate engineering training into courses for draughtsmanship at Government Training Centres or adult training centres run by individual firms. Unfortunately, this view has not always prevailed either with the Government or with some large firms." The Ministry of Education and the Scottish Education Department also drew attention to the need for draughtsmen to have some understanding of the principles of design and said that "as yet, little is done in the courses of technical education which they follow to develop such understanding."

106. The Association of Technical Institutions and the Association of Principals of Technical Institutions told us that instruction in mechanical engineering design had at one time been offered by many colleges in Higher National Certificate courses, but had been withdrawn mainly because the Institution of Mechanical Engineers did not recognize it as an exemption subject for their examination. The trend has been to substitute courses in specialized branches of engineering which are required by the Institution's Rules for Examinations.

107. Many of the Committee's witnesses, on the other hand, thought that the provision for technical education was on the whole satisfactory and particularly commended the courses in product design, jig and tool design and other associated subjects at Full Technological Certificate level in the new Mechanical Engineering Technicians' Course of the City and Guilds of London Institute. The main criticisms of witnesses focussed on the arrangements for permitting students from industry to attend the courses provided or which could be provided if there were a demand.

108. Commenting upon the City and Guilds of London Institute courses, the Association of Teachers in Technical Institutions said: "We see this type of course as producing that important middle link in the design team. We hope that there will be no undue restriction in the formation of these new courses, and that steps will be taken to ensure the attendance of suitable students. . . . It is already evident that the full value of the new courses cannot be obtained through evening work, or even through orthodox forms of day release." The Draughtsmen's and Allied Technicians' Association strongly endorsed the view of the Central Advisory Council for Education that "as a long-term aim sandwich courses should be regarded as the standard method of training for technicians. Where, in the immediate future, this is not possible, the Association also supports the recommendation of the Central Advisory Council that block release should replace day release. The experience so far, with block release schemes and sandwich courses, has been very encouraging." This view was also supported by the Minister of Education in the 1961 White Paper, *Better Opportunities in Technical Education* and in a circular on the organization of further education published in February, 1963.

109. The evidence of engineers in industry confirmed that there is a wide disparity of views and practice among engineering employers on arrangements for training drawing-office staff, granting block release and encouraging apprentices and others able to benefit from more thorough academic teaching.

We gathered that the criticism was mainly directed at small and medium-sized firms; most of the big engineering companies already take considerable trouble about their apprentices and are willing to finance part, or in some cases most, of the cost of sending suitable apprentices to college or university. The Draughtsmen's and Allied Technicians' Association said that the nationalized industries were particularly enlightened in this matter and that training both in quantity and quality as well as promotion for designers, was better in the the public sector of industry than in the private.

110. We concluded from this part of our evidence that the main requirement was for measures to raise the standard of education and training of draughtsmen and other technicians engaged in design to the level that is already current practice in some of the bigger firms in private industry, in the nationalized industries and in Government establishments. As with the practical training of professional engineers, we feel that the cost of providing adequate training for draughtsmen and technicians in properly organized apprentice schemes, with block release for all and sandwich courses for some, is a burden which the smaller firms cannot and should not be expected to bear. There should be national standards for apprentice training and those who are able and willing to run apprentice schemes to the approved standards should be indemnified.

111. Several witnesses told us that the effect of the present wide variety of attitudes among employers to the value of education and organized training was to discourage draughtsmen from striving to acquire better qualifications; those who did not strive or failed to qualify had as much chance of employment in a design team as those who were successful. More uniform standards and recognition of qualification will certainly remove this disincentive. Several of our witnesses pointed out that more ought to be done to encourage older men in design teams at all levels to attend suitable courses and otherwise to improve their competence. We certainly do not wish to see introduced into design offices in Britain the kind of rigid stratification which we were told is common in drawing offices in America where there are sometimes six or seven grades of draughtsmen below the professional engineer grade and almost impassable barriers between the grades. The traditional mobility of promotion in British drawing offices is an advantage which should be retained; apprentices entering a drawing office should feel that there is no bar to their eventually qualifying as professional engineers, with the help and encouragement of their employer, if they have the ability.

Textbooks and teaching aids

112. In our discussions with witnesses about the education and training of designers, two other matters were brought to our attention—the shortage of suitable textbooks in English, and the need for research to develop teaching aids such as films and teaching machines. The shortage of textbooks is probably closely related to the shortage of qualified teachers and the small remuneration usually offered. The shortage of qualified mechanical engineers, and particularly of mechanical engineers with design experience, affects the teaching profession as much as, if not more than, industry. If there were more teachers with more time to experiment with methods of teaching and to discuss and codify the results, it is probable that more textbooks would be written.

113. Dr. D. G. Christopherson of Durham University thought much could be done to improve the teaching of engineering drawing and to increase the

interest of students in this subject by the use of visual aids and teaching machines. A set of instructional films could present to students as much material in six hours as they now had presented to them in a course of lectures extending over a year. He told us that some dental teaching was being done successfully in this way. As far as we were able to discover no effort is being applied to the development of such aids to the teaching of mechanical engineering—which, in view of the shortage of teachers, is surprising. Up to the present, however, some technical colleges are still restricted as to space and apparatus, but progress has been made and the current programme of investment in college building and equipment will make possible a greater use of, and experimentation with, mechanical aids to education.

(6) Professional Institutions

114. The attitude of the Professional Institutions and particularly that of the Institution of Mechanical Engineers is an important factor affecting the quality of mechanical engineering design in Britain. Without design there can be no engineering, and the quality of design largely determines the success of engineering enterprise. Discussions within the Institutions during recent years have shown an awareness that more emphasis ought to be given to design in engineering education in order to identify and encourage design talent as well as to inculcate a more general appreciation of the importance of good design. Nevertheless in its statement of the "qualifications required of a professional mechanical engineer" the Institution of Mechanical Engineers makes no reference to ability to design, although it does list a good basic knowledge of engineering drawing. Nor is design mentioned in the "principles underlying the education and training necessary to lead to these qualifications." The "qualifications requisite for Associate Membership" prescribe that the candidate shall be aged 26 years, have passed the Institution Examination or an exempting examination, have had adequate practical training, have had sufficient practical experience and have held a post of professional responsibility in mechanical engineering; design is not specifically mentioned.

115. Reference to the "Rules for Examination" shows that engineering drawing, the grammar of the professional engineer, is a required subject in Part 1. The syllabus for Part 2 is concerned almost entirely with engineering science and is analytical in concept. Part 3 covers industrial administration; matters affecting design and its organization form a small part of the syllabus, but there is no requirement for a candidate to demonstrate his ability to apply his knowledge of engineering science to the solution of a design problem; there is no design paper.

116. In its publication "The Practical Training of Professional Mechanical Engineers" the Institution recommends a minimum period of practical training of two years made up of a preliminary period of basic training in workshop practices occupying six to nine months followed by secondary training. For secondary training there are five choices depending on the ultimate sphere of activity of the trainee. Of these, three, leading to careers in manufacture, design and development or commercial activities, include four to six months in all to be spent in the planning, product design, jig and tool design and commercial offices; that leading to a research career proposes a period of three months to be spent in the planning, product design and commercial offices; the fifth, operation and maintenance, includes no planning or design office experience.

Thus the two years of practical training may not include any drawing office or design experience at all and at most will contain two to three months on product design.

117. The requirements of the Institution also largely determine what is taught in technical colleges. " All college courses for Higher National Certificate and Higher National Diploma and the subjects within the courses are related to the educational requirements of the professional bodies concerned " (Association of Principals of Technical Institutions). Thus the neglect of design in the syllabus for the Institution's examination has led to the virtual disappearance of courses in design as such from mechanical engineering curricula at technical colleges. The extensive teaching of the theory of specialized branches of engineering science is, we think, no substitute.

118. In contrast to the Institution of Mechanical Engineers, The Institution of Civil Engineers places great emphasis on design in its requirements for corporate membership. Candidates must in general have spent at least one year in an engineer's office and since 1956 this period, together with the remainder of the practical training, must have been under the supervision of a civil engineer named in an index. In addition, at a professional interview at which he must produce " at least two and not more than four sheets of drawings . . . made by the candidate," he must show that he has " acquired adequate practical knowledge of the design and construction of such works as are comprised within the profession of civil engineer." The main exception permitted is the substitution of research experience for service in an engineer's office and of a thesis or published papers for drawings.

119. Several witnesses drew our attention to the relative difficulty experienced by designers in securing corporate membership of the Institution of Mechanical Engineers. The Principal of the Birmingham College of Advanced Technology wrote that the Institutions " in assessing a man for corporate membership show more interest in the number of men he controls than in the quality of work he is doing. This discourages good potential designers from sticking close to the drawing board, the only place they can practise and extend their own understanding and development of the art." The Steering Committee of the National Engineering Laboratory considered that " The requirements of the major institutions for corporate membership do not take sufficient account of the importance of design, but place a disproportionate emphasis on the number of staff controlled. It should be possible for a designer at an appropriate level to obtain corporate membership even if he controls no subordinate staff." The Management Consultants Association suggested that " If the senior institutions were to introduce some alternative subjects in their syllabuses in order to raise designers to professional status, it might be expected that more highly qualified people would engage in this occupation." The Society of British Aircraft Constructors—" Apart from the Royal Aeronautical Society, increased recognition of designers by other Professional Institutions would help to overcome the present difficulty." Professor J. Diamond of Manchester University informed us of a meeting of six eminent engineers in the North West convened by Mr. G. A. J. Begg, Past Chairman of the North Western Branch of the Institution of Mechanical Engineers, at which it had been agreed that " The Professional Institutions could do a great deal to improve the state of affairs if, firstly, they would so frame their rules for membership that they included a qualification in design, in other words, before a man were admitted as a

Corporate Member he should establish to the Council's satisfaction that he had actually carried out a suitable piece of design work himself and seen the results of his efforts put into practice. Secondly, the Institutions should take more conscious action in publicizing the work of engineering designers and, in particular, describing the work of designers to sixth-form schoolboys. The glamour, excitement and adventure of engineering design should be constantly impressed on the impressionable mind of the youth." Mr. D. B. Welbourn of Cambridge University was even more specific, "The quickest way to achieve an improvement would be for the Institution of Mechanical Engineers to follow the Civils by instituting a compulsory oral examination on a design project."

120. We consider that a balanced design team requires both professional engineers and technicians. Many technicians are accepted into Student and later into Graduate Membership of the Institution of Mechanical Engineers. Unless they can secure transfer to Associate Membership before age 38, or in special circumstances 40, the Institution makes no subsequent provision for them. This generates considerable pressure to admit higher qualified technicians to full Corporate Membership. We believe that many such people have been admitted in recent years but that it has happened much less often to technicians in the design field than to those whose responsibilities for supervision are more obvious, for example in development activities. This has undoubtedly still further depressed the status of those who have been turned away.

121. In consequence, various organizations have been formed to cater for technicians; in the field of mechanical engineering design there is the Institution of Engineering Designers. This body is performing a useful function but its existence still further emphasizes a separation between the professional engineer designer and his supporting technical staff. Too often there is, in practice, a separation which leads to a difficulty or failure in communication. "There ... appears to be a gap between the engineering director level and the drawing-office staff level. Communication across this gap is far worse now than it was before the war" (Admiralty). We are in favour of any steps which are likely to improve communication and for this reason we deprecate any measures which serve to emphasize the separation.

122. Finally, several of our witnesses felt that the widespread use of the designation "engineer" to describe people ranging from the semi-skilled workman to the professional practitioner led to a debasement of the currency and contrasted the position in this country with that on the continent of Europe where different titles are used to describe people with different levels of qualification. They felt that the Professional Institutions should try to resolve this anomaly by seeking to restrict the description "engineer" to individuals with full professional qualifications or by coining a new term. The existing usage of "Chartered Engineer," "Chartered Mechanical Engineer," etc., has not yet been effective in correcting the erroneous view widely held by the lay public.

(7) Standards and standardization

123. Many witnesses drew our attention to the restrictions which British Standards placed upon the latitude of designers to propose more efficient and economical solutions to engineering problems. British Standards are not legally enforceable, but in so far as they are believed by industry to represent

the best practice and to incorporate the most up-to-date knowledge, it is understandable that they are insisted upon by some customers and by insurance companies. This would be all very well if British Standards did in fact lay down the best practice in the light of the latest knowledge available. Some undoubtedly do, but there are serious exceptions.

124. We were given evidence that

(i) there are six new schedules of specifications for wrought copper and copper alloys which contain all the necessary information at present covered by thirty-nine British Standards of which only two are in line with the schedules. It has been agreed by the British Standards Institution to retain these thirty-nine standards in addition to the six schedules and to revise the standards in due course to bring them in line with the schedules, thus having forty-five publications. The effect of retaining the thirty-nine is that designers continue to be able to justify the use of obsolete technology. Other instances were given of cases where the British Standards Institution had issued omnibus editions of a British Standard but had not simultaneously cancelled all the individual British Standards that the omnibus edition was intended to replace;

(ii) design formulae in British Standards for pressure vessels were demonstrated to us to be mutually inconsistent and all call for lower stresses and consequently heavier construction than are necessary with modern fabrication techniques and materials (this subject is understood to be currently under review by the Institution);

(iii) British manufacturers in many fields are not sufficiently forward-looking in arranging for the promulgation of British Standards acceptable for export trade or as international standards. The result is that international standards tend to be based on foreign (and particularly German) national standards rather than on the best British practice;

(iv) there are numerous important fields in which there are no standards. These include pumps, reduction gears other than marine, dimensions for heat exchangers, materials-handling equipment, machine tools other than gear cutting machines;

(v) foreign standard specifications often give more information than British. Consequently, there is more incentive to the designer to use and the customer to demand the use of these standard specifications.

125. The last review of the organization and constitution of the British Standards Institution was carried out by the Cunliffe Committee appointed by the President of the Board of Trade in 1949. In its report, published in 1950, this Committee generally approved the principle of procedure by agreement, but considered that the Institution itself should take a more active part in initiating action for the preparation of standards. The Committee also suggested that the attempt should be made to obtain user representation on B.S.I. Committees.

126. The Lemon Committee on standardization in the engineering industry appointed by the Minister of Supply, which reported in 1949, had already made similar suggestions and had in addition recommended that standards, whether national or of a limited character, should reflect the best current practice

and that, if there were a considerable demand for differing qualities of standard products, it should be met not by averaging but by providing more than one standard.

127. We were given evidence of the difficulty about providing for adequate user representation. The evidence summarized above suggests that the British Standards Institution is still not able to take sufficient initiative in the preparation of new standards or in the withdrawal of obsolete standards. We think a possible reason for this is that the staff of the B.S.I. is not large enough, and consequently not sufficiently specialized, to cover adequately the fields of industry, particularly engineering, in which the establishment of proper standards is a matter of vital importance to the trading economy. The Committee was glad to learn that the Board of Trade have recently changed the method of calculating the Government grant-in-aid to the B.S.I. so as to relate it more closely to the level of contributions from industry. The B.S.I. is believed to be planning to use the expected increase in revenue to increase its staff. It is, however, thirteen years since the Cunliffe Committee reported and we think there is a case for another review of the B.S.I.'s method of operating as it affects design standards, a review which might perhaps be undertaken by the Institute itself rather than by an outside committee.

128. Our evidence included proposals for the increased mechanization of the more routine parts of the draughting process. Systems are being considered which use electronic techniques to read, store and reproduce drawings and design specifications. The possibility of such systems depends upon a fairly high degree of standardization of parts and frequently-used mechanisms. There are already in use in industry systems of classification of standard parts, notably the Brisch system, which, even without the introduction of advanced aids to the draughting process, considerably simplify the work of the design and the production departments. We would like to see appropriate classification systems more widely adopted as a first step towards the introduction of more mechanization into drawing offices.

(8) Purchasing procedures

129. No one can have a greater influence on the quality of engineering design than the customer. If customers insist on buying only the best designed products then inferior designs will not continue to be produced. There is nearly always pressure on purchasing authorities to accept the lowest tender, but the lowest tender may not offer the best design, nor the cheapest solution to the problem in the long run. Some of the disadvantage of tendering procedures were exposed by Admiralty witnesses. "The system of Government financial control makes it very difficult for the Admiralty to break the normal policy of accepting the cheaper tenders for a contract rather than the best technical solution for the operator's requirements. It would probably be to the benefit of the country as a whole for the Admiralty to support firms with comparatively high overheads resulting from their own research and development costs, apprentice training schemes, etc., rather than those firms who can produce the cheapest products because their contribution in the research and development field is small. In this light it might well pay the Admiralty and the country to give more for a product incorporating the fruits of research work and thus encourage better design." The same points were made by the Atomic Energy Authority who wrote: "In the purchase of special equip-

ment, much depends on the placing of the contract. Providing there is a careful choice of contractor according to the type and quality of the equipment required, it is found that the mechanical design work is generally well executed in so far as it interprets the specification with sound mechanisms and good quality workmanship. . . . The engineer who is buying equipment has good reason to remember the expression *caveat emptor*. The risks in buying are less likely when the arrangements for purchases are made with technical representatives of high design ability." In other words, the lowest tender is likely to be based on less research, to allow for less development and to be more prone to failure, and therefore is unlikely to be the best overall solution.

130. The Authority's mention of the importance of the specification is timely. The customer's specification and the designers' conversion of this into a set of design requirements are vital steps in securing a satisfactory solution. Writing of some of the engineering reasons which delayed British civil aircraft from going into service on the planned dates, the British Overseas Airways Corporation said: " In general British firms and, maybe, technical departments of the Ministries concerned, have found it difficult to appreciate the commercial and operational objectives for air transport . . . and in respect of mechanical design there appears to have been difficulty at all levels in appreciating the very different requirements of a civil aircraft from the military. . . . If the major aircraft firms had the above difficulties, the component manufacturers, who were even further removed from airline contacts, experienced greater difficulty. The airlines requirements being interpreted by the aircraft manufacturer were passed on to the component manufacturers secondhand; . . . and, finally, there was the problem that the aircraft manufacturer did not, through lack of experience and knowledge, specify adequately the conditions under which he required the component to operate in his aircraft." British European Airways said: " Technical equipment of the kind required for the modern transport aeroplane cannot be designed and put on the market on a competitive basis without the close and detailed knowledge of the customer's requirements and usage conditions. Many British firms still do not seem to be prepared to go to the trouble of finding out what it really is the customer needs." One way in which specifications for service aircraft had been unsatisfactory was pointed out by an Air Ministry witness who said that " the aircraft designers lacked a firm Air Ministry statement of the requirements for reliability "; and " specifications for aircraft and weapons systems should state firm reliability requirements." The importance of the specification cannot be over-emphasized. It is the key both to design and to procurement problems.

131. The Atomic Energy Authority also drew attention to the responsibilities of the purchaser. It is he who must see to it that he gets good value for money: having stated his requirements fully he must judge which of the competing tenders provides the best overall solution; and if he is satisfied by none of them, he must be prepared to indicate a better approach or to produce his own design.

CHAPTER VI

THE REMEDIES

(1) The importance of design and the status of designers

132. Design " is the very heart and origin of all engineering activity."* This is a fact which is not recognized by many engineering managements in the place which they give to the design function in their business organizations, nor in the pay and prospects which industry at large offers to design engineers. Failure to appreciate the great importance of design in engineering industry and the failure to recruit into engineering enough of the abler men and women coming up through the education system are facets of a bigger national problem. At the root of this problem lie the social attitudes of the citizens of this country which are in marked contrast to the attitudes of citizens of other industrially advanced countries; in British eyes other professions such as medicine, the law, university teaching and scientific research have a higher social prestige than engineering, and, indeed, on available information, are more lucrative. Social attitudes can only be changed very slowly. Nevertheless, we think a start can be made to impress upon managements the vital importance to Britain of industrial innovation and its dependence on engineering design and to spread amongst the younger generation, from whom engineering industry must draw its recruits, a better understanding of the rewards and satisfactions of careers in engineering industry.

133. *We therefore recommend :*

(i) that D.S.I.R. in collaboration with the Federation of British Industries, the Engineering Employers' Federation and other organizations representing engineering industry, should organize a series of meetings and conferences to demonstrate to senior managements the importance of good design as a major factor affecting the financial success of engineering businesses;

(ii) that D.S.I.R. should initiate a programme of publicity, using all available media, to bring to public attention the national importance of engineering industry and of engineering as a profession. Particular attention should be focused on the career opportunities in engineering and the demands they make upon the qualities of character and intellect of young men and women;

(iii) that D.S.I.R. and the Education Departments should consult with the broadcasting authorities about extending the use of educational programmes to prepare young men and women for further education and careers in engineering and to encourage them to choose this course; that D.S.I.R. should also consult the television authorities about the use of other television programmes watched by young people and their parents to stimulate interest in and increase knowledge of careers in engineering;

(iv) that the Engineering Institutions Joint Council should increase their efforts to encourage the development of engineering activities in schools and should organize visits by pupils to works and by members

* WALLACE, P. J., *The Engineer*, 19th April, 1963.

to schools to advise teachers and pupils on the opportunities for interesting and rewarding careers in engineering industry.

(2) The influence of the Professional Institutions

134. We agreed with many of our witnesses who were members that the Professional Institutions, and particularly the Institution of Mechanical Engineers, could do a great deal more to enhance the status of design engineers within the engineering profession. There are a number of ways in which this could be done: more emphasis should be given to competence in design as a qualification for corporate membership, some design office experience could be made a general condition for membership, and recognition of the importance of supporting staff in design offices could be given by creating a special class of membership for technicians with design qualifications. This last step would we think greatly stimulate the team spirit so essential in most engineering activities and particularly in design.

135. *We therefore recommend:*

(i) that the Institution of Mechanical Engineers in admitting to corporate membership should require experience in design from all candidates not engaged in research and should satisfy itself as to candidates' professional competence in borderline cases by professional interview;

(ii) that the Engineering Institutions Joint Council should consider the introduction of a new category of membership to cater for engineering technicians including draughtsmen, and should discuss with the Institution of Engineering Designers the possibility of some form of affiliation;

(iii) that the Institution of Mechanical Engineers should give greater weight to the professional content of work than to the number of staff controlled when considering applications for any grade of membership from those engaged upon design work;

(iv) that, where appropriate, other Professional Institutions should consider taking similar steps.

(3) Education and training of professional engineers and draughtsmen

136. In the evidence given to the Committee there was no consensus of opinion about how design was to be taught or at what stage in the education and training of the engineer. We have already noted that the subject is much under discussion and that a large number of different approaches to the problem are being tried out in universities and colleges up and down the country. The willingness to experiment is healthy and is certainly to be encouraged. It is important that the experience gained from the trial of different methods of teaching and of different arrangements of courses should be shared, discussed and assessed. We also think that there is scope for more research on teaching methods.

137. Our consideration of the various types of engineering education offered in this country and abroad has led us to conclude that what is known in Britain as the "sandwich" course is the most suitable preparation for a career as a professional engineering designer. This type of course is already required in colleges preparing students for Diplomas in Technology. We are sure that

the prestige of the Diploma in Technology will increase as increasing numbers of engineers with this qualification enter industry. We hope that more of the ablest school leavers will opt for this type of higher education. We would also hope that similar arrangements for the inclusion of practical experience could be made a requirement in Associateship courses in Scottish Central Institutions.

138. In so far as universities consider that it is their function to prepare engineers for careers in industry, we feel strongly that they should normally encourage six to twelve months' experience in industry as a highly desirable qualification for admission to undergraduate courses in engineering.

139. It is equally important that teaching staff in universities and colleges should themselves have had experience in industry and that some at least should have practised as designers.

140. We agree with the White Paper *Better Opportunities in Technical Education* (Cmnd. 1254)* that the aim should be for the sandwich course also to become the normal form of education for technicians as well as for professional engineers. Meanwhile, we would like to see more uniform standards of integrated education and training for drawing-office staff at all levels, including block release for appropriate courses. While we defer to the views of the education authorities and the teaching staff associations that more can be done to introduce design subjects into technical college courses, we are on the whole impressed with the provision which now exists for technical education. The main need is for industry to make more use of the resources now available, or in process of being created, by releasing more students for courses and senior men who can help with the teaching and, generally, by building up closer relationships with the schools and colleges which can serve their needs.

141. The value of the "sandwich" course depends as much on what the student learns in industry as on what he learns in college or university. We consider that the periods spent in industry by students of universities and colleges of technology, as well as apprentice training for technicians, should be most carefully planned and supervised by the university or college authorities in collaboration with the firms selected for this training, or by Boards set up for the purpose, and that the students should be tested on what they have learned during their industrial training.

142. Students intending to enter universities or colleges of technology to study for degrees or diplomas in engineering could with advantage share their first period of industrial training with other apprentices of the same age. There should probably be some form of day release to attend lectures and tutorials or seminars and students should be encouraged to write essays or read papers describing and commenting upon their experience. Lectures should be arranged to explain the functions of the various departments in the firm in which they have successively received training. During subsequent periods in industry all students should spend some time in the drawing office, including the detail drawing office, but students intending to be designers should also gain adequate experience of the production, planning and costing departments.

143. We realize that the implementation of such a scheme as we have in mind covering the practical training of professional engineers and technicians implies

* Also the corresponding Scottish White Paper (Cmnd. 1245).

much closer collaboration between industrial employers and university and college authorities than is now usual. It also means that firms which receive students under such a scheme will assume additional burdens and not all firms will be either willing or able to participate. We are in favour of the introduction of some arrangement for reimbursing firms who participate in the scheme and taxing those who do not.

144. *We therefore recommend:*

(i) that D.S.I.R. should explore the means of providing facilities and financial support for periodic conferences of teachers of engineering in universities and colleges of technology to discuss methods of teaching engineering subjects, to compare the results of experiments with new methods and arrangements of courses, to promote the production of textbooks and to initiate researches into new methods;

(ii) that D.S.I.R. should continue to encourage universities and colleges to apply for grants to support research into teaching methods for engineering subjects and should appoint a panel of experts to advise on the extension of research in this field;

(iii) that the universities should encourage students to undertake a period of industrial training as a normal qualification for entering engineering departments;

(iv) that in the selection and promotion of individual staff in engineering departments of universities and colleges of technology, importance should be attached to achievements in design or production as well as to achievements in research;

(v) that the Institution of Mechanical Engineers should endeavour to obtain the agreement of departments of mechanical engineering in universities and colleges of technology, of industry, and, where appropriate, of the Education Departments, to minimum requirements for the duration and content of the periods of industrial training of university and college students of engineering; and that the new regulations should make a minimum period of drawing-office experience compulsory for all students;

(vi) that the scheme for industrial training described in the White Paper, Cmnd. 1892, *Industrial Training: Government Proposals,* should be applied to the training of professional engineers and technicians as soon as possible after the scheme comes into operation.

(4) Advanced training in design

145. We have stressed the need for experiment in the teaching of design at the undergraduate level. There is also room for experiment in teaching a generalized approach to design at postgraduate level. We were impressed by the evidence on work in this field at Cambridge and at Imperial College, London. Design engineers trained in this approach should be better able to solve unusual problems, or to provide new solutions to familiar ones, than those trained in a more orthodox way. Nevertheless, if the supply of qualified designers is to be increased, most postgraduate training will have to be specialized.

146. In their submission to us the Engineering Institutions' Joint Council said: "There is a need for some postgraduate centres of engineering design in specialized fields such as automobile engineering and shipbuilding, providing for an interchange of ideas between industry and academic institutions. These centres should be located in areas where there are expert designers who could be seconded from industry as part-time teachers. Students must learn by actually engaging in design. These centres must emphasize the synthetic element and must be developed under the aegis of industry."

147. We strongly support the Joint Council's suggestion. In this report we have already referred to the arrangements for advanced training in design at the College of Aeronautics, Cranfield, for the aircraft and aero-engine industries and at Manchester College of Science and Technology for the machine tool industry. The College of Aeronautics has also recently started courses for engineers from the automobile industry. In some other institutes of a specialized kind the tendency is to place the emphasis on research; we believe that equal emphasis should be placed on design, so that design draws its inspiration from current research and research is stimulated by the needs of design.

148. Specialized design institutions serving particular industries must depend heavily on their industries for help in teaching, practical training and the supply of real design problems for study, and this will to some extent determine the geographical location of institutes.

149. ***We therefore recommend :***

(i) that consideration should be given to the establishment of institutes at suitable universities and colleges for advanced studies of design in particular industrial fields. Each institute should be closely associated with research in the appropriate field and with the industry it serves;

(ii) that industry should support the establishment of appropriate facilities in every way and particularly by releasing suitable staff to assist with teaching on a part-time basis, by encouraging the use of planned courses of training in industry under joint supervision, and by sponsoring suitable junior staff to attend full-time courses in advanced design institutes;

(iii) that universities and colleges should in appropriate cases grant associate or visiting professorships, readerships and lectureships to appropriate persons in industry;

(iv) that universities and colleges should encourage their staff to accept design consultancy work, and, where necessary, grant leave of absence for this purpose, to ensure that they remain in touch with design developments in industry;

(v) that universities and colleges should not only provide internal courses but should also co-operate experimentally with industry in the provision of extra-mural training in advanced design;

(vi) that courses of suitable quality and duration, whether carried out intra-murally or extra-murally, should lead to the award of a higher degree or equivalent qualification having parity with, but distinguishable from, those awarded for research.

(5) Improved draughting methods

150. We have stressed the importance of raising the status and remuneration of designers and we have expressed our conviction that it would be a sound investment for industry to pay more attention to design and particularly to detail design. We believe that it is possible to raise the productivity of designers and particularly of detail designers and so to make this increased investment more attractive. Although the use of draughting machines has become widespread, the basic method of producing designs, by drawing on paper with pencil or ink, has not changed in principle for many years. Our evidence shows that modern techniques of reproduction and developments in electronics make possible a new approach to this problem which could result in large savings in the production of engineering drawings. Increasingly, too, the detail designer will need to communicate directly with an automatically controlled machine tool. To a growing extent his output will be in the form of instructions on punched or magnetic tape as well as of conventional drawings and specifications. Many of the problems to be solved are common to the improvement of draughting methods and to the instruction of automatically controlled machine tools; indeed the former might be regarded as the first step in achieving the latter. Both will make extensive use of automatic data processing, for example, to store details of common features in a form readily available to the designer, to generate complex functions and to approximate to them by interpolation. It will be essential to develop a computer language for use in mechanical engineering and it is highly desirable that there should be a single, universal language.

151. ***We therefore recommend :***

(i) that D.S.I.R. should give whatever financial or other support is appropriate to research into improved methods of producing engineering designs and to the development of promising applications;

(ii) that the Institution of Mechanical Engineers should take steps to initiate discussion of this subject so as to formulate a generally agreed philosophy and to stimulate the adoption of a universal computer language for use in mechanical engineering.

(6) Development contracts

152. Contracts for the development of articles required by the Defence Services and civil development contracts provide Government with an opportunity to influence the standards of mechanical engineering design in industry. It is probable that most if not all defence development contracts are awarded to firms having first-class design teams; indeed such contracts have been a potent force in creating and improving the design capacity of that sector of industry which serves the Defence Departments. The need to secure similar advances in other industries has been emphasized, for example, in the Mitchell report on the machine-tool industry.* This is one of the declared objectives of the D.S.I.R. civil development contracts scheme which was introduced four years ago and has been somewhat slow to grow. The National Research Development Corporation has also encouraged the creation of high quality design teams in those areas where it has been able to invest. We feel that more could be done by both D.S.I.R. and N.R.D.C. and we support the efforts being made by both

* *The Machine Tool Industry*, a Report by the Sub-Committee of the Machine Tool Advisory Council appointed to consider Professor Meliman's Report to the European Productivity Agency, Board of Trade, September, 1960.

these organizations to extend their activities in these directions. In particular, we welcome D.S.I.R.'s recent initiative in seeking out projects which merit support by means of development contracts.

153. *We therefore recommend :*

(i) that Defence Departments should continue to use their development contract procedure to encourage and improve high quality design teams in industry;

(ii) that civil development contracts should be used for the same purpose;

(iii) that D.S.I.R. should continue to regard this as one of the main objectives of its civil development contract scheme and should seek to expand this activity rapidly by seeking out new projects as well as by encouraging industry to come forward with its own proposals;

(iv) that N.R.D.C. when placing contracts should insist upon the highest standards of design.

(7) Government purchasing

154. One-third of the annual national investment in plant, machinery, vehicles and ships is on account of central and local government and public corporations. The Committee believe that Government can exert a considerable and perhaps decisive influence on standards of mechanical engineering design by adopting appropriate procedures for both Government and public authority purchasing. By definition good design is economical and the best design is the most economical, although not necessarily the lowest in first cost. Therefore to pursue a policy of purchasing none but the best-designed articles seems to be only common sense. To do so requires that three steps should be taken. First, the specification of requirements should be carefully drawn up and should define the object to be achieved rather than a particular way of achieving it; the specification must be complete yet concise, unambiguous yet not unnecessarily restrictive. Second, tenders must be properly judged. The lowest-priced tender will not necessarily provide the most economical solution when other costs are taken into account. Third, if the purchasing authority is not satisfied with the quality of the designs offered to meet its specifications it must be able to suggest a better approach and, if necessary, to produce its own pace-setting design.

155. If Government Departments and public authorities are to pursue this course, then their professional staffs, particularly those engaged in design or advising on purchasing, must be of high quality and they must ensure that adequate research is carried out in their respective fields to provide the basis for future improved designs. Many Departments and authorities already adopt a progressive purchasing policy of this sort; it is clear from evidence submitted that the Defence Departments are well aware of its advantages and try to make their major purchases in this way. The evidence shows that the nationalized industries, notably the Central Electricity Generating Board and the airlines, also adopt such a policy for major purchases. We believe that similar criteria are not always applied to the purchase of smaller items although in total they are not less important.

156. *We therefore recommend :*

(i) that Government Departments and public authorities should insist on the highest standards of mechanical engineering design when making purchases of ships, aircraft, weapons, machines, plant supplies

or equipment; the solution most economical over the designed life should be accepted, particularly if it is a British design, rather than the lowest tender;

(ii) that purchasing authorities should review their procedures for specifying requirements and for judging tenders to ensure that this is done; this review should include consideration of the adequacy of their staff concerned.

(8) Data sheets

157. Ways of bridging the gap between research and design were examined by the Committee on the Management and Control of Research and Development under the Chairmanship of Sir Solly Zuckerman,* who recommended that "as a means of increasing the effectiveness of the dissemination of the results of research, much more should be done by D.S.I.R. and by the industrial research associations on the lines of 'data sheets' such as those prepared by the Royal Aeronautical Society." This problem was also examined by the Director of the National Engineering Laboratory in an Andrew Laing Memorial Lecture to the North East Coast Institute of Engineers and Shipbuilders; he, too, concluded that data sheets were a most valuable means for conveying research results to designers and favoured an extension of their use. The need has been appreciated by the Draughtsmen's and Allied Technicians' Association who have produced a valuable series of handbooks for their members. Many firms and some Government Establishments have also produced data sheets for use within their own organizations. We have already referred to the recent work of the joint Committee of the Scientific Instruments Manufacturers Association and the Scientific Instrument Research Association in producing a design handbook for their industry. In other countries, notably West Germany, design manuals are in common use.

158. The Committee agrees that data sheets and manuals are an effective and economical way of making up-to-date basic engineering knowledge available to designers. We believe that they are particularly useful in raising the standards of detail design. The data sheets produced by the Royal Aeronautical Society are admirable for this purpose and we believe could, with advantage, be adopted as the model over the whole field of engineering. We do not agree that they should be produced by D.S.I.R. or by industrial research associations. While these organizations are well aware of the most recent research results in their own fields they do not, in the main, have experienced design staffs. Nor does any organization exist which could co-ordinate their efforts effectively. We believe that only the Professional Institutions are sufficiently broadly based to produce authoritative documents of this sort. To do so they will require the active support of D.S.I.R. and the industrial research associations, but will also be able to call upon members engaged in research, design, consulting, production and other activities. To supplement these voluntary efforts they will almost certainly need additional expert technical staff such as are employed by the Royal Aeronautical Society. We consider that it would be appropriate for these activities to be supported by Government grant.

159. ***We therefore recommend:***

(i) that the Professional Institutions should be invited to prepare and

* Office of the Minister for Science, July, 1961.

issue design manuals or data sheets similar to those already prepared by the Royal Aeronautical Society;

(ii) that D.S.I.R. laboratories and the industrial research associations should be required to give active support in their respective fields;

(iii) that D.S.I.R. should consider making grants to the Professional Institutions to allow them to employ the necessary expert technical staff for this purpose;

(iv) that the data sheets should be available for sale to non-members.

(9) British Standards Institution

160. Our evidence on the effect of British Standards on the quality of British mechanical engineering design has led us to conclude that in some fields present British Standards unnecessarily restrict the designer's scope for applying the results of recent research and for developing original solutions to design problems. We would like to see the British Standards Institution giving a more positive lead in the introduction of new standards incorporating the most up-to-date practice and in extending the field covered by British Standards. We consider that the Institution should have power unilaterally to withdraw British Standards which they consider, on the best advice available, have become obsolete.

161. We think it probable that most of the criticisms of British Standards and of the British Standards Institution arise from the Institution being insufficiently staffed for the immense task now being imposed upon it by industrial society. If the number of the Institution's staff could be increased so that it could employ qualified specialists in all the more important fields, we have no doubt that the Institution could play a major part in raising the standards of design practice throughout industry.

162. ***We therefore recommend*** that the British Standards Institution should examine the adequacy of its resources and their deployment to ensure that British Standards always encourage and never inhibit good design practice.

(10) Licences

163. In the earlier part of our report we have expressed some disquiet at what we consider to be a too great dependence on foreign licences on the part of some firms and some parts of engineering industry. The international trade in licences and " know-how " is healthy and is believed to be growing rapidly. We believe that it should be a matter of national policy for a trading country like the United Kingdom, which has few natural resources other than its brains and skills, to seek to expand this trade and to achieve a credit balance in its trade on this account. There is at present no information on which to base any estimate of the United Kingdom's net position. This seems to us to be an important deficiency in essential economic information. Knowledge of the position would assist those whose business it is to frame policy for investment in research and development and would provide additional incentive to those capable of contributing to increased " exports " in this field.

164. ***We therefore recommend*** that the Board of Trade should consider whether and by what means it would be possible to collect and publish information on income and expenditure incurred under licence agreements between British and foreign companies.

APPENDIX I

Written evidence was received from the following organizations:

PUBLIC AND PRIVATE INDUSTRY

Amalgamated Engineering Union
Association of British Chemical Manufacturers
British Chemical Plant Manufacturers' Association
British Engineers' Association
British European Airways
British Internal Combustion Engine Manufacturers' Association
British Overseas Airways Corporation
British Transport Commission
Committee of Directors of Research Associations
Council of Industrial Design
Draughtsmen's and Allied Technicians' Association
Electricity Council
Federation of British Industries
Gas Council
General Post Office
Joint Iron Council
Machine Tool Trades Association
Management Consultants' Association
National Coal Board
National Council for Quality and Reliability
Society of British Aircraft Constructors
United Kingdom Atomic Energy Authority
Water Tube Boilermakers' Association

GOVERNMENT DEPARTMENTS

Admiralty
Board of Trade
Department of Scientific and Industrial Research
Ministry of Aviation
Aeronautical Research Council
Ministry of Education
Scottish Education Department
War Office

Association of Teachers in Technical Institutions

Association of Principals of Technical Institutions

Association of Technical Institutions

National Council for Technological Awards

Birmingham University

Bristol University

Cambridge University

Durham University:
- King's College, Newcastle
- Durham Colleges

Leicester University

Liverpool University

London University:
- Imperial College of Science and Technology
- King's College
- University College

Manchester University

Manchester College of Science and Technology

Nottingham University

Oxford University

Sheffield University

University College of South Wales and Monmouthshire, Cardiff

University College, Swansea

Aberdeen University

Edinburgh University

Glasgow University

Royal College of Science and Technology, Glasgow

St. Andrew's University

College of Aeronautics, Cranfield

Birmingham College of Advanced Technology

Battersea College of Advanced Technology

Bradford Institute of Technology

Bristol College of Technology

Loughborough College of Technology

Welsh College of Advanced Technology, Cardiff

Heriot-Watt College, Edinburgh

Paisley Technical College

Association of Consulting Engineers

Engineering Institutions' Joint Council:
- The Institution of Chemical Engineers
- The Institution of Civil Engineers
- The Institution of Electrical Engineers
- The Institution of Gas Engineers
- The Institute of Marine Engineers
- The Institution of Mechanical Engineers
- The Institution of Production Engineers
- The Institution of Structural Engineers

Institution of Engineering Designers

IN ADDITION the following gave their views to members of the Committee on a personal basis:

E. W. M. Britain, Esq., B.Sc.(Eng.), M.I.Mech.E.: *Fodens Ltd.*

L. H. Dawtrey, Esq., M.I.Mech.E.: *The Standard Motor Co. Ltd.*

F. Dollin, Esq., B.Sc.(Eng.), M.I.Mech.E.: *C. A. Parsons and Co. Ltd.*

Sir George Edwards, C.B.E., D.Sc., F.R.Ae.S., F.I.A.S.: *British Aircraft Corporation Ltd.*

Sir Arnold Hall, M.A., A.C.G.I., F.R.Ae.S., F.R.S.: *Bristol Siddeley Engines Ltd.*

S. H. Henshall, Esq., B.Sc.(Eng.), A.M.I.Mech.E.: *Crossley Brothers Ltd.*

J. L. Hepworth, Esq., B.Sc.(Eng.), M.I.Mech.E.: *Hepworth and Grandage Ltd.*

W. M. Heynes, Esq., M.I.Mech.E., M.S.A.E.: *Jaguar Cars Ltd.*

C. L. Old, Esq., B.Sc.(Eng.), M.Sc.(Tech.), M.I.Mech.E.: *Vickers Ltd.*

A. A. Rubbra, Esq., C.B.E., B.Sc., F.R.Ae.S., M.I.Mech.E.: *Rolls-Royce Ltd.*

Harold Smith, Esq., M.Sc., D.I.C., A.R.C.S.: *Imperial Chemical Industries Ltd.*

R. A. Wilson-Jones, Esq., B.Sc.(Eng.), M.I.Mech.E.: *The Enfield Cycle Co. Ltd.*

Oral evidence was received from the following individuals and organizations:

Admiralty

Captain R. G. Raper, R.N.

Air Ministry

Group Captain P. C. Cleaver, O.B.E., A.M.I.Mech.E.
Wing Commander E. R. Madger
W. J. F. Wellard, Esq., O.B.E., B.Sc., M.I.E.E., A.M.I.Mech.E., A.C.G.I., D.I.C.

Battersea College of Advanced Technology

W. Carnegie, Esq., Ph.D., M.I.Mech.E.
C. E. Dear, Esq., A.M.I. Prod.E.

Birmingham University

Professor S. A. Tobias, M.A., D.Sc., Ph.D., A.M.I.Mech.E.

British Motor Corporation Ltd.

A. Issigonis, Esq.

Scientific Instrument Manufacturers' Association Joint Committee and British Scientific Instrument Research Association

A. W. Smith, Esq., B.Sc., A.R.C.S.
H. G. Oughton, Esq.
J. Thomson, Esq., M.A., D.Sc., F.Inst.P., M.I.E.E.
Miss S. Fitzmaurice-Kelly, B.A.
R. E. Burnett, Esq., M.A., M.I.E.E., A.Inst.P.
R. E. Fischbacher, Esq., B.Sc., A.R.C.S.T., A.M.I.E.E.
G. M. E. Williams, Esq., B.Sc., A.M.I.E.E.
L. Finkelstein, Esq., M.Sc., A.Inst.P., A.M.I.E.E.
} *Northampton College of Advanced Technology*

Brown Brothers Ltd., Edinburgh

C. C. Mitchell, Esq., O.B.E., B.Sc., M.I.Mech.E.

Cambridge University

Professor Sir John Baker, O.B.E., D.Sc., Sc.D., M.I.C.E., M.I.Mech.E., F.R.S.
J. Reddaway, Esq., M.A.
D. B. Welbourn, Esq., M.A., M.I.Mech.E., M.I.E.E.

Central Electricity Generating Board

Sir Christopher Hinton, K.B.E., D.Sc., M.I.C.E., M.I.Mech.E., M.I.Chem.E., M.I.E.E., F.Inst.F., F.R.S.A., F.R.S.

College of Aeronautics, Cranfield

Professor J. Loxham, C.G.I.A., M.I.Mech.E., M.I.Prod.E., F.B.I.M.
Professor A. H. Lefebvre, B.Sc., Ph.D., D.I.C., A.M.I.Mech.E.
Professor G. A. Whitfield, B.Sc., F.Inst.P., F.R.Ae.S., M.I.E.E.
D. Howe, Esq., S.M., D.C.Ae.

Committee of Directors of Research Associations

H. R. Mills, Esq., Ph.D., M.I.Mech.E. (The British Iron and Steel Research Association)

R. Weck, Esq., Ph.D., M.I.C.E., M.I.Mech.E. (British Welding Research Association)

L. E. Prosser, Esq., B.Sc.(Eng.), A.K.C., M.I.Mech.E., M.I.W.E. (British Hydromechanics Research Association)

Draughtsmen's and Allied Technicians' Association and Society of Technical Civil Servants

G. Doughty, Esq.
J. Mortimer, Esq.
C. Cooper, Esq.

Durham Colleges

D. G. Christopherson, Esq., O.B.E., D.Phil., M.I.Mech.E., F.R.S.

English Electric Company Ltd.

G. S. Bosworth, Esq., M.A., M.I.Mech.E., M.I.E.E., F.R.S.A., A.R.Ae.S.

Glasgow University

Professor G. D. S. MacLellan, M.A., Ph.D., M.I.Mech.E.

Ministry of Education

C. R. English, Esq., B.Sc.(Eng.), M.I.Mech.E. (Chief Inspector of Technical Education)

Motherwell Bridge and Engineering Company Ltd.

N. H. McLean, Esq.,

National Council for Technological Awards

Vice-Admiral Sir Frank Mason, K.C.B., M.I.Mech.E., M.I.Mar.E.
Sir Walter Puckey, Kt.
A. W. J. Chisholm, Esq., B.Sc., M.I.Mech.E., A.M.I.Prod.E.
F. R. Hornby, Esq., M.B.E., M.A.

P. & O. Research and Development Company Ltd.

T. W. Bunyan, Esq., B.Sc., M.I.Mech.E., M.I.Mar.E.

Rollo Industries Ltd.

J. M. Rollo, Esq., O.B.E., B.Sc.

Rolls-Royce Ltd.

A. Holmes Fletcher, Esq., B.Sc., M.I.Mech.E.

Royal College of Science and Technology, Glasgow

Professor A. S. T. Thomson, D.Sc., Ph.D., M.I.Mech.E.
Professor A. W. Scott, C.B.E., B.Sc., Ph.D., A.R.C.S.T., M.I.Mech.E., M.I.Chem.E.
T. Allen, Esq., B.Sc.

Short Brothers and Harland Ltd., Belfast

H. G. Conway, Esq., M.A., M.I.Mech.E.

Sir Ewart Smith, M.A., M.I.Mech.E., M.I.Chem.E., F.R.S.

University College of South Wales and Monmouthshire

Professor S. P. Hutton, Ph.D., D.Eng., M.I.Mech.E., A.M.I.C.E., A.F.R.Ae.S.

Vauxhall Motors Ltd.

M. Platt, Esq., M.Eng., M.I.Mech.E.

Printed in England for Her Majesty's Stationery Office by McCorquodale, London, S.E.

A5828. Wt. 3079. K32. 6/63.

Published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
York House, Kingsway, London w.c.2
423 Oxford Street, London w.1
13A Castle Street, Edinburgh 2
109 St. Mary Street, Cardiff
39 King Street, Manchester 2
50 Fairfax Street, Bristol 1
35 Smallbrook, Ringway, Birmingham 5
80 Chichester Street, Belfast 1
or through any bookseller

Price 4*s*. 0*d*. net

S.O. Code No. 47—247

DEPARTMENT OF SCIENTIFIC AND
INDUSTRIAL RESEARCH

ENGINEERING DESIGN

Report of a Committee Appointed by the Council for Scientific and Industrial Research to Consider the Present Standing of Mechanical Engineering Design

LONDON
HER MAJESTY'S STATIONERY OFFICE
1963

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH
STATE HOUSE, HIGH HOLBORN,
LONDON W.C.1

The Rt. Hon. Viscount Hailsham, Q.C.,
Lord President of the Council and
Minister for Science.

MY LORD,

On 10th May, 1962, in accordance with your wishes, the Council for Scientific and Industrial Research appointed a Committee:

> "to consider the present standing of mechanical engineering design in relation to the United Kingdom engineering industry and practice overseas; and
> to recommend any changes which are likely to result in improved engineering design of British products, including, in particular, changes in education and training."

The Report of the Committee was received and discussed by the Council at their meeting on 13th June, 1963. The Council recommended its publication.

I am, My Lord,
Your obedient Servant
(*Signed*) H. ROXBEE COX,
Chairman.

13th June, 1963.

COMMITTEE ON ENGINEERING DESIGN

G. B. R. FEILDEN, Esq., M.A., M.I.Mech.E., F.R.S.: *Chairman*
Group Technical Director, Davy-Ashmore Limited; Member of the Council for Scientific and Industrial Research.

S. H. GRYLLS, Esq., M.A., M.I.Mech.E.
Director and Chief Engineer, Rolls-Royce Limited, Motor Car Division.

M. C. DE MALHERBE, Esq., Ph.D., D.I.C., A.M.I.Mech.E.:
Senior Lecturer, Department of Mechanical Engineering, Imperial College of Science and Technology, University of London.

Professor O. A. SAUNDERS, M.A., D.Sc.(Eng.), M.I.Mech.E., F.Inst.F., F.R.Ae.S., F.R.S.:
Past President of the Institution of Mechanical Engineers;
Member of the Council for Scientific and Industrial Research.

The Hon. PENELOPE K. PIERCY, M.A.: *Secretary*
Head of Economics Section, Department of Scientific and Industrial Research.

In addition, B. K. BLOUNT, Esq., C.B., M.A., B.Sc., D.Phil.Nat., F.R.I.C., Deputy Secretary of the Department of Scientific and Industrial Research, and F. D. PENNY, Esq., B.Sc., M.I.Mech.E., Deputy Director of the National Engineering Laboratory of the Department of Scientific and Industrial Research attended meetings of the Committee and acted as members.

CONTENTS